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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

A COMPARATIVE ANALYSIS OF UNITED STATES MILITARY ACADEMY (USMA) CADET SLEEP

by

Alexandra K. Deangelis

June 2018

Thesis Advisor:	Nita L. Shattuck
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Second Reader:	Lyn R. Whitaker

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The results from a four-year longitudinal study executed from 2003–2007 at the United States Military Academy (USMA) indicated that Cadets sleep significantly less than the amount recommended for their age group. The current report presents the initial findings from a two-part study undertaken in the fall of 2017 to determine whether the sleep and nap duration of Cadets attending USMA has changed in the intervening years. Actigraphy data from 269 Cadets from all four year groups was collected for analysis. The results indicate that current Cadets sleep more at nighttime than their predecessors both on school nights (current average = 5.24 hours), with current Cadets obtaining 0.19 hours (11 minutes) more than their predecessors ($p < 0.001$), and on weekend nights (current average = 6.95 hours), with current Cadets obtaining 0.47 hours (28 minutes) more than their predecessors ($p < 0.001$). Sleep duration was significantly influenced by day type (school day or weekend), gender, and year group, corroborating the findings of the previous study. Cadets nap longer on weekends and most frequently on Thursdays. The results of this analysis extend the body of knowledge about sleep in the late-adolescent military population and provide insight into the sleep patterns and behaviors of USMA Cadets. Suggestions for additional research are also proposed.

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A COMPARATIVE ANALYSIS OF UNITED STATES MILITARY ACADEMY (USMA) CADET SLEEP

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MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	analysis of variance
app	activity log application
CBT	Cadet basic training
EEG	electroencephalogram
FSS	fatigue severity scale
FAST	fatigue avoidance scheduling tool
GPA	grade point average
NREM	non-rapid eye movement
PSG	polysomnography
PSQI	Pittsburgh sleep quality index
REM	rapid eye movement
SAFTE	sleep, activity, fatigue, and task effectiveness
SD	standard deviation
se	standard error
SWS	slow wave sleep
USMA	United States Military Academy
WAM	wrist actigraphy monitor

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EXECUTIVE SUMMARY

Sleep affects every facet of our lives, from mood and performance to health and safety. Too often, however, the first thing we sacrifice to achieve our daily goals is the time to sleep. Cadets attending the United States Military Academy (USMA) undergo a rigorous selection process before entering a program designed to prepare them for military life. Despite this selection and training process, Cadets sleep needs are still similar to those of other college-age students. The results from a four-year longitudinal study executed from 2003-2007 at USMA indicated that Cadets obtained significantly less sleep than was recommended for their age group. The current report presents the initial findings from part one of a two-part study undertaken in the fall of 2017 to determine whether the sleep and nap duration of Cadets attending USMA has changed in the intervening years.

Actigraphy data from 269 Cadets across all four year groups were collected for analysis. The amounts of daily sleep (sleep and naps occurring over a 24-hour period), nighttime sleep, and naps the Cadets obtained were calculated. The results indicated that current Cadets on average obtain more nighttime sleep than their predecessors both on school days (difference=11.4 minutes, $p<.0001$) and on weekends (difference=28.2 minutes, $p<.0001$). Both the average daily and nighttime sleep durations were influenced significantly by the day type (school day or weekend), gender, and year group, corroborating the factors that were significant in the previous study. As in the previous study, female Cadets tended to sleep more than male Cadets, especially on school nights. Cadets napped an average of 1.27 hours (1 hour 16 minutes) (SD = 0.69 hours) on school days; average nap duration was influenced the most by day type. Cadets tended to take more naps on Thursday than all other days.

While Cadet nighttime sleep has improved, the average of 5 hours and 37 minutes of sleep and naps (daily sleep) that Cadets obtain on school days is still drastically less than the 7 to 9 hours recommend for young adults. These findings indicate the continued presence of a striking sleep debt in USMA Cadets, which still needs to be addressed. Suggestions for additional research are also proposed.

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I. INTRODUCTION

A. OVERVIEW

Among the competing time demands of a modern adult, the list of required and desired activities is endless. Making time for certain activities requires making sacrifices in other areas, and the first thing that most people sacrifice in the name of getting it all done is sleep. The National Sleep Foundation recommends that adults ages 26–64 years old sleep at least seven to nine hours per night (Hirshkowitz et al., 2015). Yet a 2013 Gallup survey of over 1,000 adults ages 18 and older reported that they received an average of only 6.8 hours of sleep per night (Jones, 2013). This finding was further corroborated by an analysis of sleep intervals conducted by the Jawbone company (maker of wearable fitness devices) in 2014 which found that, among wearers of their device in 21 U.S. cities, the average amount of sleep was just over 6.8 hours nightly (Ferdman, 2014). With the increase in competing demands over the years, the amount of sleep obtained each night is unlikely to have risen in the intervening years since these two previous surveys. While 6.8 hours of sleep may appear to be acceptable, the fact that it is on the low-end of the National Sleep Foundation's requirement spectrum for adults is cause for concern, especially considering the increasing amount studies linking the amount of sleep to bodily health, satisfaction, happiness, and success (Walker, 2017).

The same pressures and desires to get more done each day exist for college students. For these "young adults," who traditionally range in age from 18–22 years old, it is also recommended that they sleep from seven to nine hours per night, although a flexible range of sleep of up to 11 hours per night is mentioned in the National Sleep Foundation's recommendations (Hirshkowitz et al., 2015). Yet, numerous sleep studies have revealed that young adults do not generally sleep in the recommended duration range for a myriad of reasons, both personal and biological.

If the pressures of normal college life result in a lack of sleep for the average college student, one can imagine that the lack of sleep may be even more pronounced when faced with the additional requirements placed on Cadets who attend The United States Military

Academy (USMA) at West Point. In addition their rigorous academic program, an education which is considered to be on-par with Ivy-league universities, Cadets are required to attend a mandatory morning formation at 6:55 AM, meet specific daily grooming standards, participate in a sport either at the NCAA level or club-level, maintain military fitness standards, attend mandatory military courses or classes over much of the traditional summer break, receive quarterly training in subjects such as equal opportunity and sexual harassment, and train in military tactics and leadership. In their final year, Cadets are required to hold leadership positions among their peers in the Corps of Cadets. These USMA-specific requirements are in addition to the Cadets having the same desires as other college-attending peers: to interact, watch television, date, and enjoy free time. As the requirements placed on Cadets cannot be ignored, it is likely that they find time for all their activities by decreasing the amount of sleep they obtain nightly.

This thesis analyzes data acquired from the first of a two-part, yearlong study exploring the amount of sleep Cadets in each of the four year groups (or Classes) obtain over two-weeks in the fall and spring semesters. The data for this first part of the analysis was collected from approximately October 23 to November 6, 2017. Chapter I of this thesis explores the reason for undertaking this study. Chapter II reviews the published literature pertinent to the study of sleep, especially in the college-age population, and explores some recent advances in sleep research. Chapter III explains the methods used to recruit participants and collect data for this study, as well as the analysis process used for the sleep data. Chapter IV provides results from an analysis of the fall data collection and compares the current results to those obtained in the four-year longitudinal study conducted on the USMA Class of 2007 from 2003 to 2007. Chapter V discusses the findings, provides conclusions resulting from this analysis and recommends future avenues of exploration.

B. PROBLEM AND PURPOSE

Results from a four-year longitudinal study of the West Point Class of 2007 indicated that Cadets spent a large portion of their academic career operating under a significant sleep debt (Miller, Shattuck, & Matsangas, 2010). The analysis conducted by Miller, Shattuck, and Matsangas (2010) concluded that the average school night sleep

(sleep occurring during the night only) obtained by Cadets was 5.05 hours (SD=1.03 hours), and the average weekend nighttime sleep was 6.48 hours (Standard Deviation (SD) =1.85 hours). In addition, female Cadets slept more daily than their male counterparts (Miller et al., 2010). In response to the study results, USMA leadership enacted a mandatory weekday "lights out" policy in an attempt to address the issue of Cadet sleep debt. However, the intervening 10 years have seen numerous technological and societal changes that continue to make obtaining the recommended sleep difficult**,** despite the ongoing existence of the lights-out policy. As a result, USMA leadership requested an updated sleep study to determine whether there have been any changes to the amount of Cadet sleep, compared to the results from the Class of 2007 study.

This thesis specifically addresses the question of whether there have been changes in the amount of time that Cadets sleep by analyzing sleep data collected from a sample of Cadets across all four year groups during the fall of 2017. It further seeks to determine what factors play a role in the amount of sleep Cadets obtain and examines Cadet napping patterns. Finally, it explores how Cadets utilize their time through an examination of self-reported activity logs and assesses the validity of using self-reported activity logs as a method of determining sleep duration. The results of this thesis provide USMA leadership with updated information on the state of the Corps of Cadets, which can in turn influence administrative actions and decisions at West Point. It also adds to the body of literature on the sleep duration of young adults and explores the use and accuracy of digital self-reported activity logs.

C. APPROACH

Cadets were asked to participate in the sleep study through a combination of email advertisement and recruitment carried out at various locations around the USMA campus. Volunteer participants were asked to fill out a series of questionnaires at the onset of the study. The questionnaires included a series of questions about demographic characteristics, information on the Cadet's roles and duties, the Epworth Sleepiness Scale, the Pittsburgh Sleep Quality Index (PSQI), and the Morningness-Eveningness Questionnaire. Participants were then provided a user name and password to an online application (app) that allowed participants to provide an electronic self-reported account of their daily actions for the two weeks of the experiment. Finally, each participant was issued a wrist activity monitor (WAM), which recorded the magnitude of their individual movement in 1-minute intervals.

Participants were instructed to wear the WAM and complete the activity log for each day that they wore the WAM. At the end of the fall study period, the WAMs were collected and the resulting movement information was downloaded, reviewed, cleaned, and analyzed to provide information on daily and nighttime sleep duration and naps for each individual participant. A subset of participant activity logs was also analyzed to provide information on Cadet daily time utilization.

II. LITERATURE REVIEW

Because this thesis focuses on the sleep habits of a group of young adults attending college, a large portion of this literature review focuses on teenage and young adult sleep. However, an understanding of some of the processes that affect sleep at every age group is necessary to comprehend the importance of sleep and its effects on the human body. This review begins with a description of human sleep and the biological processes that control it, as well as a review of the current research surrounding the reasons that humans need sleep. It then moves into specific information on teenage and young adult sleep, the processes that affect their sleep, and the possible effects of young adults not obtaining enough sleep. Differences between male and female sleep patterns are also explored. Naps and their process and purposes are then addressed, followed by a review of general causes of sleeping difficulty. The review concludes with a synopsis of how sleep is currently quantified and calculated for research purposes.

A. AN OVERVIEW OF SLEEP

Humans must have sleep to function. The Merriam-Webster online dictionary defines "sleep" as "the natural periodic suspension of consciousness during which the powers of the body are restored." Personal experience implies that this definition is accurate, yet scientists have not yet conclusively determined how the sleep state developed in humans and why it is necessary to our survival, although we may be getting closer to an answer. Experimentation through the years has shown that multiple processes function together to both prepare and drive the human body toward sleep.

1. Circadian Rhythm

The first and perhaps most important of these processes is known as the circadian rhythm. The circadian rhythm is best described as a natural clock by which many of the body's processes operate. Although early sleep studies involving participants who lived in the absence of all external stimuli such as natural light or clocks indicated a natural circadian cycle length of 24.7 to 25.2 hours a day (Max-Planck-Gesellschaft, 2007), more recent studies have concluded that the human circadian rhythm on average cycles at about

24.18 hours each day, in the absence of natural light or time-keeping cues (Czeisler et al., 1999). This cycle closely corresponds with the 24-hour cycle exhibited by the Earth's movement around the sun.

There are three biological processes that function as both a part of, and indicators of, the circadian rhythm and exert an influence on human sleep: core body temperature, melatonin secretion and feedback loops, and cortisol secretion and feedback loops. Figure 1 illustrates the general levels of each of these biological processes throughout a typical 24-hour cycle. The hypothalamus, located deep within the human brain, plays the primary role in monitoring and controlling the human body's reaction to these biological processes, contributing enormously to the control and expression of the circadian rhythm. A study conducted by Morton et al. (2005) concluded that deterioration of the hypothalamus may be the cause of disrupted sleep patterns in patients with Huntington's disease, a disease characterized by neurodegeneration of multiple sites in the brain.

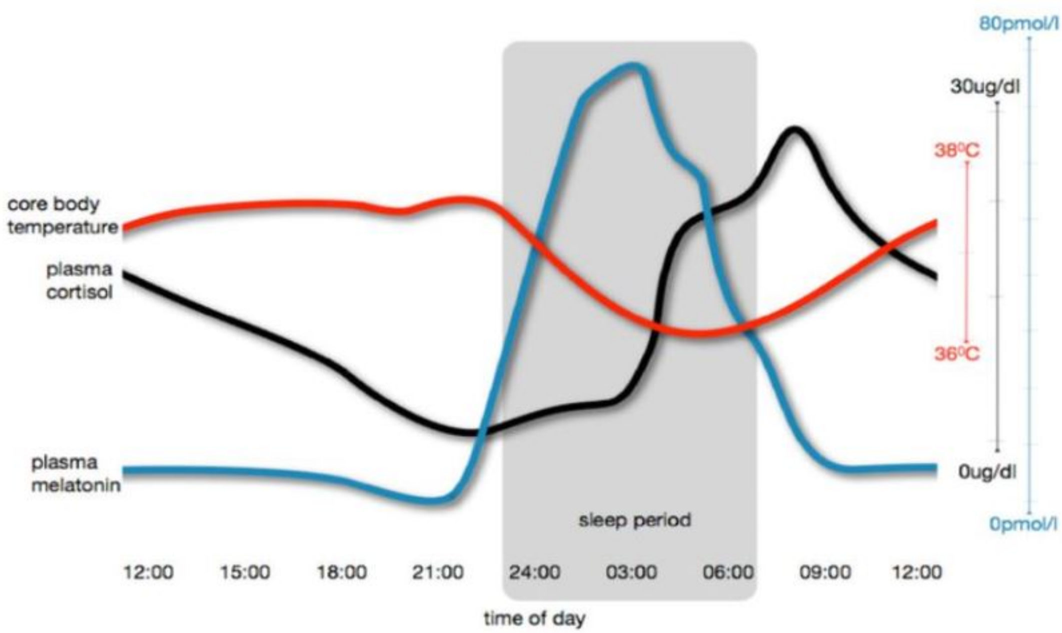

Figure 1. The 24-hour rhythms of cortisol, melatonin and body temperature. Source: Hickie, Naismith, Robillard, Scott, and Hermens (2013).

Buckley and Schatzberg (2005) concluded that interactions that affect the production and reception of cortisol in the body appeared to affect the circadian rhythm, specifically by playing a role in the amount and quality of sleep. Wakamura and Tokura (2000) investigated the effect of light on both body temperature and sleep and found that exposure to bright light during the day and in the morning greatly decreased the minimum core body temperature at night and led to more wakefulness the following day. Raymann, Swaab, and Van Someren (2008) found that a slight increase in the body's skin temperature, which is inversely related to core body temperature, improved sleep quality by decreasing the number of natural awakenings at night and promoted quick descent into deeper stages of sleep.

As for melatonin, Cajochen, Kräuchi, and Wirz-Justice (2003) found that the administration of melatonin appeared to speed up core body cooling and advance the onset of sleep. A more in-depth review of the role of melatonin in the maintenance of circadian rhythms and the ways melatonin can specifically be manipulated to affect sleep will be reviewed in a later section. The results of these and multiple other studies indicate that cortisol, melatonin, and body temperature play an important and interactive role in the regulation of the circadian rhythm and thus, also regulate sleep.

There is some flexibility within the body's natural sleep-wake cycle. The process of "entrainment" involves making an action, usually consistently or repeatedly, that alters the body's innate circadian rhythm to accommodate a desired change in the human sleep-wake cycle. For example, anticipation of wake time has been shown to affect the body's production of cortisol, assisting in awakenings earlier than the natural circadian rhythm would generally dictate (Born, Jansen, Marshall, Mölle, & Fehm, 1999). Experiments involving the effect of natural light versus that of a mixture of artificial (indoor) light and natural light on melatonin production have shown that the body's circadian rhythm naturally migrates toward a sunrise-sunset related timeframe in the absence of all artificial light (Wright et al., 2013). This result indicates that the body's natural circadian rhythm can be "entrained" to function on a different timeline, but will quickly revert to its natural rhythm when allowed.

Further experimentation by Stothard et al. (2017) indicates a seasonality to entrainment, whereby the onset of winter with its shorter days and longer nights leads to a longer biological night in the innate circadian rhythm. In their experiment, the longer biological night persisted both during exposure to only natural light and during exposure to artificial light, although the duration of the biological night (and thus the amount of sleep) was shorter in participants exposed to artificial light. A second experiment in the same study indicated that entrainment—in this case, entrainment back to the body's natural circadian rhythm—can happen in as short as 48 hours. In the study by Stothard et al., two days of exposure to only natural light during the summer was enough to shift the already entrained circadian rhythm toward a more sunset-sunrise related timeframe, although not as completely as reported in the study by Wright et al. (2013). The results of these studies demonstrate that the underlying biological rhythm of the sleep-wake cycle may be shifted or altered by personal choice or natural exposure.

2. Sleep Stages

The sleep period can be broken into two separate and distinct stages, which alternate in predictable cycles throughout sleep duration: non-rapid eye movement (NREM) and rapid eye movement (REM). These stages can be monitored using an electroencephalogram (EEG), which measures the brain's electrical activity while the participant sleeps. Sleep onset is dominated by NREM, which is further divided into three separate stages: N1, N2, and N3 ("Natural Patterns of Sleep," 2007). EEG depictions of each of these stages can be found in Figure 2, which shows the changes in the brain's electrical activity throughout each stage of sleep.

Each of the three NREM stages generally indicate an increasing difficulty in arousing the sleeper from that stage of sleep (Carskadon & Dement, 2011, p. 2). Sleep onset begins in NREM stage N1 and progresses through stages N2 and N3 before finally entering REM sleep. This cycle then repeats itself approximately every 90 minutes, only briefly re-entering the N1 stage, and concludes with increasing amounts of time spent in REM sleep as the sleep state lengthens in time ("Natural Patterns of Sleep," 2007). A depiction of NREM and REM sleep cycles can be found in Figure 3. In total, REM sleep generally accounts for 20–25% of the total time asleep (“Natural Patterns of Sleep,” 2007).

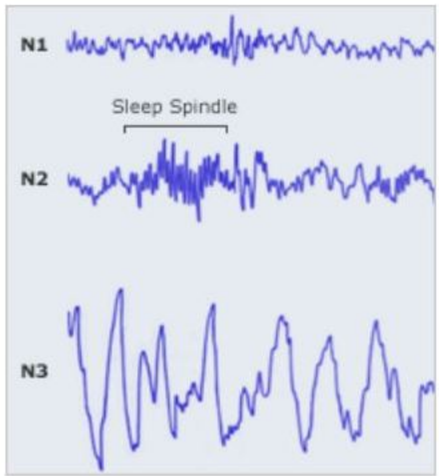

Figure 2. EEG recordings showing the three stages typical of NREM sleep. Source: “Natural Patterns of Sleep” (2007).

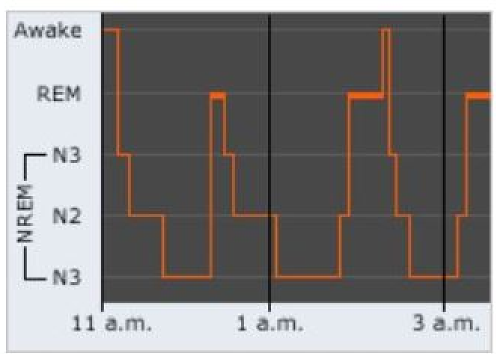

Figure 3. A hypnogram of the typical patterns of REM and NREM sleep cycles throughout the night. Source: “Natural Patterns of Sleep” (2007).

a. REM Sleep

Rapid eye movement (REM) sleep is quite an interesting phase of sleep; testing and EEG recordings indicate that the brain is very active during REM, and yet the human body remains in an almost paralyzed state (Carskadon & Dement, 2011, p.19). Early studies have shown that REM sleep is loosely coupled with the body’s circadian rhythm but appears to be more closely aligned with body temperature (Czeisler, Zimmerman, Ronda, Moore-Ede, & Weitzman, 1980). Czeisler et al. (1980) showed that the amount of time spent in REM sleep increased when sleep occurred during the body's natural dip in temperature, which generally coincides with the body's circadian "night." This pattern indicates that REM sleep is a natural and necessary part of the human sleep cycle.

The importance of REM sleep has been demonstrated in other experiments. In one such experiment, when participants were deprived of REM sleep, their pain thresholds were lower than when they received sleep with normal amounts of NREM and REM sleep combined (Roehrs, Hyde, Blaisdell, Greenwald, & Roth, 2006). Roehrs et al. (2006) also demonstrated that even regular sleep loss (containing both NREM and REM sleep stages) had the same pain-heightening effect, and that an accumulative loss of sleep over time led to a heightened feeling of pain. Thus, sleep, and especially REM sleep, has a measurable effect on the perception of pain. REM sleep also appears to affect creativity in problem solving. Cai, Sarnoff, Harrison, Kanady and Mednick (2009) provided evidence that participants allowed REM sleep (either as a nap or as full sleep) showed significant improvement in problem-solving as compared to participants who were either allowed quiet wakeful time or a nap consisting of only NREM sleep. These results together indicate that sleep, and specifically REM sleep, play a significant role in human performance.

b. NREM Sleep

Although many studies have focused on REM sleep, it does not mean that non-rapid eye movement (NREM) sleep is any less important to human functioning. An exhaustive review of published literature pertaining to types of memory and their performance under various amounts and stages of sleep deprivations was conducted by Rauchs, Desgranges, Foret and Eustache (2005). The review indicates the important relationship between NREM, REM, and more specifically Slow Wave Sleep (SWS), which occurs in stage N3 of NREM sleep. It also indicates that both REM and NREM sleep are critical for problem-solving and memory consolidation. However, the need for each type of sleep stage appears to vary depending on the type of memorization, recall, or learning task being studied.

In their review, Rauchs et al. (2005) utilize the Tulving categories of the different types of memories, which can be broken down into: episodic memory, semantic memory, perceptual representation systems, and procedural memory. Episodic memory is memory that involves specific events defined by their location and the time at which they were learned. Semantic memory involves things that a person knows but did not learn from personal experience and includes common knowledge facts such as the letters of the alphabet. Perceptual representation systems, or perceptual memory, involves memorization by categorizing the incoming information. Finally, procedural memory is comprised of skills that we acquire, and can be further broken-up into a subset of three additional memory types. Figure 4 depicts the relationship between the type of memory necessary for successful recall, and the stages of sleep that appear to be the most necessary for improved performance of that type of memorization or learning. It should be noted that for most of the depicted types of memory, NREM sleep appears to play a necessary and critical role in the successful application of that type of memory.

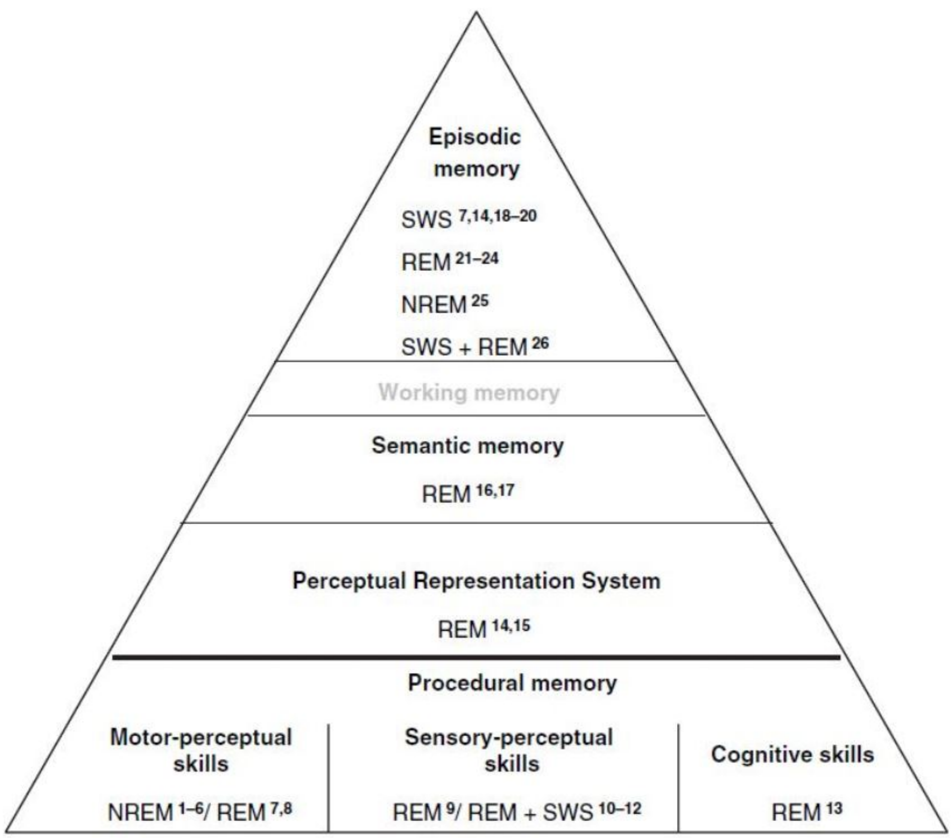

Figure 4. Relationships between sleep stages and Tulving's memory systems. Source: Rauchs et al. (2005).

3. Reasons We Need Sleep

Despite ongoing research, we still cannot pinpoint the exact reason why we need sleep. Krueger, Frank, Wisor, and Roy (2016) reviewed six leading explanations for sleep, among them: bodily health and immunity, caloric savings, and brain/memory connectivity. Based on their review of pertinent literature, memory connectivity appears to be an important feature of sleep. However, guidelines for the specific amount of each stage of sleep that humans must attain to thrive has not been determined. Nonetheless, research indicates that sleep appears to affect almost every aspect of human life.

a. Memory

A growing body of work concludes that sleep is critical to memory function, which in turn aids the human ability to learn. Besides Krueger et al. (2016) who concluded that the main function of sleep was to exercise and retain the connections (memories) made during the day, the literature review conducted by Rauchs et al. (2005) provided numerous examples where sleep improved memory across a wide breadth of memory types and skill types. (See Figure 4, in the previous section). Research delving into the specific physical processes of how memories are stored indicate that storage occurs in the brain during sleep (Sejnowski & Destexhe, 2000). Rasch and Born (2013) reviewed studies indicating that when humans sleep, the brain consolidates and redistributes memories, aiding long-term memory storage. A study conducted by Nissan et al. (2006) compared participants with insomnia to participants with no obvious sleep disorder. Both groups conducted a task testing their memory after sleep. Results showed that while both groups improved after a night of sleep, the participants with insomnia improved less than the participants without a sleep disorder, again emphasizing the important role that sleep plays in the human brain and memory.

b. Performance

Several studies suggest that sleep plays a significant role in human performance, especially in tasks involving physical action and attention to detail. One must look no further than accident statistics to find that sleepiness results in car-related fatalities at rates close to the rate of accidents involving alcohol intoxication (Kloss, Szuba, & Dinges, 2002). In their research, Kloss, Szuba and Dinges (2002) also reviewed a study showing that participants with sleep apnea, a sleep disorder that results in fragmented sleep states, performed poorer on a driving simulation task than matched peers without any sleep issues. A meta-analysis conducted by Pilcher and Huffcutt (1996) of 19 journal articles recording the effects of various levels of sleep deprivation on performance concluded that sleep deprivation affected the performance of reasoning-related tasks the most and affected physical-related tasks as well, but to a lesser degree. A 1995 review by Akerstedt (1995) also concluded that lack of sleep, especially in shift workers and night workers, led to impairment in the performance of their job. Akerstedt (1995) further proposed that alertness could be predicted by a combination of participant sleepiness, the time since the participant last awakened, and the participant's sleep inertia (the amount of disorientation a sleeper experiences upon awakening). The results of these studies indicate that sleep plays a role in the successful performance of everyday and work-related tasks.

c. Health

The amount of sleep (or the lack thereof) also affects the physical health of the human body. Lange, Dimitrov and Born (2010) concluded that many of the antibodies that comprise the human body's immune system operate on a circadian rhythm that is closely tied to the human sleep-wake cycle. The immune system appears to be especially susceptible to the duration of sleep, with even a single night of total sleep loss resulting in immediate changes to the immune system (Ackermann et al., 2012; Faraut et al., 2011). Czeisler (2015) took this information one step further, concluding in his review of the many diseases and disorders linked to sleep deprivation that the timing, amount, and quality of sleep all contribute to overall human health.

Recent studies have focused on how the amount of sleep affects the likelihood of becoming infected with specific illnesses. Sleeping less than six hours resulted in a heightened susceptibility to catching the common cold (Prather, Janicki-Deverts, Hall & Cohen, 2015). Furthermore, a study by Orzech, Acebo, Seifer, Barker and Carskadon (2013) conducted over a semester of school by teenagers in the range of 14–19 years of age concluded that teenagers who obtained less sleep tended to be sick more often than peers who slept longer. Orzech et al. (2013) also observed that teenagers who became sick frequently slept less in the week prior to the illness than they slept in weeks when they were not ill. These results all indicate that sleep is critical to maintaining physical health.

B. SLEEP IN TEENS AND YOUNG ADULTS

In past sleep research, “adolescents” were loosely defined as the age group from around 12 years of age up to approximately 25 years old (The National Sleep Foundation, 2000), an extremely broad range of ages that encompassed numerous physical and biological changes in the adolescent body. More recent research, however, has broken this large group into two subgroups, teenagers (ages 14–17) and young adults (18-25), each with their own daily sleep requirements (Hirshkowitz et al., 2015). This section explores the changes in sleep that occur during the teenage and young adult years, and the role of sleep in young adult performance.

1. Biology Affecting Sleep

The onset of puberty is well known and documented as a time of massive change in the human body. Physically, the teen body begins to mature as hormones are produced in significant amounts, accompanied by growth and maturation. Given these disruptions to the body’s general homeostasis, it is not surprising that puberty creates changes in the circadian rhythm and sleep as well. Carskadon, Vieira, and Acebo (1993) studied pre-teenagers in the early stages of puberty, documenting a preference toward both going to bed later and waking up later in the mornings. Ronneberg et al. (2004) also found that the preference for a later timing of sleep onset in teenagers began to reverse slowly at around 20 years of age. Their findings indicate that the change in sleep patterns are closely related to the status of puberty in humans.

Carskadon, Acebo and Jenni (2004) confirmed the findings of several previous studies that showed the duration of sleep stage N3, specifically Slow-Wave-Sleep (SWS), decreased as age and level of puberty increased. Carskadon et al. (2004) also confirmed that increasing melatonin production, a signal of pending sleep initiation, was delayed in the pubertal circadian rhythm when compared to the rhythms from pre-pubertal studies. Crowley et al. (2014) found a delay in daily melatonin production as age increased from nine to seventeen years of age. These studies indicate that there are multiple biological rhythms driving teenage and young adult sleep patterns that may not simply be overridden by need or personal desire. These processes drive teenagers and young adults to stay up later, resulting in high school and college students who may feel perpetually sleepy in class (Carskadon, 1990; Carskadon, Wolfson, Tzichinsky, & Acebo, 1995, p. 92).

2. Genetics Affecting Sleep

Researchers have explored the idea that the basis of an individual's daily sleep requirement may have its roots in gene expression. In a study comparing a group of sleepers requiring longer daily amounts of sleep (greater than 9 hours) and a group requiring less daily sleep (less than 6 hours), Aeschbach et al. (2003) found that the long sleepers and short sleepers' melatonin, cortisol, and body temperature measurements were different, and were synched with their individual sleep requirements. This result indicates that an unknown entity drove each participant's circadian rhythm, and thus daily sleep requirement. Furthering this research, Hor and Tafti (2009) suggested that sleepers requiring less sleep, and those requiring more sleep, generally appeared within family groups, and noted that alterations in the expression of certain genes in mice and fruit flies had resulted in changes to those animals' sleep cycles. Goel, Basner, Rao and Dinges (2013) concluded in their review that experimental confirmation of a morningness or eveningness preference indicated that it was an inherited trait. They further stated that the differences in performance success that these trait-groups experienced when tested under sleep deprivation conditions indicated a genetic underpinning that interacts with the physical and biological cues of the circadian rhythm.

Lo et al. (2012) found that participants who possessed a variant of the PER3 gene were more affected by sleep deprivation on some cognitive tasks than other participants. More recently, Harbison, Serrano, Hansen and Lobell (2017) experimented with fruit flies and found that after multi-generational breeding for both long and short duration sleepers, approximately 80 genes appeared to broadly affect the expression of sleep duration in fruit flies. These studies indicate that in addition to external factors affecting sleep duration and expression, genetic variants can both combine and be somewhat influenced by external factors, resulting in the influence of individual sleep expression as well as individual response to lack of sleep.

3. Sleep Affecting Learning

In general, teens and young adults do not sleep enough at night. Wolfson and Carskadon (1998) reported that teenagers attending high school reported decreasing amounts of sleep over the four years of high school both during school days and weekdays. Owens (2014) reported that the teenage daily sleep duration decreased in most countries around the world as the teenagers grew older. This decline was in addition to the fact that teens were already not obtaining enough daily sleep prior to the onset of puberty.

Lack of sleep has a clear effect on academic performance. Wolfson and Carskadon (1998) reported a significant link between self-reported grades and the students' average amount of daily sleep, with students who received As and Bs sleeping more at night than their peers with lower grades. In their review, Alhola and Polo-Kantola (2007) concluded that both total and partial sleep deprivation led to decreases in cognitive function, with this result generally translating to decreased attention and alertness, slowed reaction times, and poor results in visual-type tests.

A daily sleep debt, which is incurred by not obtaining enough required daily sleep, can also be termed as "partial sleep deprivation." Harrison and Horne (2000) concluded from their review that sleep deprivation in adults affected decision-making, especially decisions that were short notice and required creative solutions. In their review, Kopasz et al. (2010) determined that a lack of sleep in teens and young adults degraded their ability to complete tasks that involved complex or abstract thinking. They also found that lack of sleep affected their performance of these complex tasks even more than the performance of simple memory tasks. Based on these findings, it is fair to say that any form of sleep deprivation, whether the loss of a single night of sleep or the gradual accumulation of sleep debt over multiple nights, has an effect on both the teenage and young adult capacity to learn, creatively solve problems, and make critical decisions.

The powerful influence that sleep has on daily performance can be observed through its effects on both physical and mental tasks. Mah, Mah, Kezirian and Dement

(2011) observed that college basketball players who slept for at least 10 hours each night experienced better results (faster sprint times, better free-throw percentages, etc.) as well as statistically significant decreases in daily sleepiness and improved feelings of well-being. On the academic side, in a study of students attending universities in Nigeria, Williams and Aderanti (2014) found that students' responses as to whether they slept long enough were positively related to their grade point average (GPA). Their results indicated that those individuals who obtained enough sleep also appeared to have better grades. The reverse was also true, in that students who slept less had lower GPAs (Williams & Aderanti, 2014). Edens (2006) reported that students exhibiting excessive daytime sleepiness, likely caused by a lack of adequate sleep in previous nights, also were more likely to engage in procrastination, an act that can sabotage academic performance. Taylor, Vatthauer, Bramoweth, Ruggero and Roane (2013) found that, among other factors, total nighttime sleep was a significant indicator of college academic performance. These results all indicate that sleep plays a significant role in promoting successful physical and academic outcomes.

4. Counteracting Sleep Loss

Prior studies indicate a significant problem with teens and young adults not obtaining enough sleep, but is there a way to counteract these effects? The most common solution to this issue, applied in some middle and high schools in the United States has been to institute later school start times. A report by Wahlstrom et al. (2014) concluded that high school start times that occurred later than 8:35 a.m. resulted in higher GPAs, fewer school days missed due to sickness, and better results on standardized testing. Other studies have indicated that delaying school start times by one hour can result in increased attention span (Lufi, Tzischinsky, & Hadar, 2011). This result compliments the results of Agostini, Carskadon, Dorrian, Coussens and Short (2017) who found that after being restricted to five hours of sleep at night, teens experienced their lowest attention times at around 8:30 a.m., a time at which many schools across the U.S. are already in full swing for the day. Based on these studies, shifting school start times to the right is likely to have a positive effect on GPA and learning ability through an increased attention span in class, and is also likely to result in improved health.

In cases where delaying class start times is not possible, are there are other reasonable measures that might be taken to lessen the effect of sleep deprivation? While it has been shown that naps can assist with short boosts in performance (Dinges, Whitehouse, Orne & Orne, 1988), it is likely that naps may not counteract the effects of sleep deprivation (Dinges, Orne, Whitehouse, & Orne, 1987). Frequently, well-meaning individuals assume that sleep deprived students can “make-up” sleep lost on the weekdays by sleeping more during the weekend. Recovery sleep does exist, and it has been proven to have a different make up, in terms of the stages of sleep, than normal sleep. (Carskadon, Acebo, & Seifer, 2001).

A study by Jay et al. (2007) determined that the measurable effects of recovery sleep on performance (after one night of sleep deprivation) is dependent on the total duration of recovery sleep, with the recommended amount being greater than 8 hours. However, the likelihood of such a lengthy sleep period occurring in today’s busy world is small. The idea of “banking” sleep prior to an anticipated loss of sleep has also ben explained. Rupp, Wesensten, Bliese, and Balkin (2009) reported that study participants who received more sleep than normal prior to a period of sleep restriction recovered more quickly and performed better than their peers who only obtained the normal amount of sleep. These studies indicate that it is possible to take actions to counteract the effects of sleep loss. However, the effects of these strategies on a large sleep debt accumulated over a long-term period have not been explored.

C. GENDER AND SLEEP

Significant differences in the sleep of female and male participants are common in sleep studies. Dorofaeff and Denny (2006) noted that more female teenage participants reported obtaining less sleep than needed than that reported by male participants. This result supports findings by Bubolz, Brown and Soper (2001) that female college students were more likely to report sleep difficulties than males. Dorofaeff and Denny (2006) also found that females slept less on the weekdays, and slept more on the weekends than their male counterparts. Alhola and Polo-Kantola (2007) noted in their review that gender-related differences in sleep stages have been reported in some studies. They also noted that women in sleep deprivation experiments generally performed better than men on some cognitive tasks. A meta-analysis conducted by Randler (2007) concluded that females were more likely to be morning-types (prefer waking in the mornings) than males, who were more likely to be evening-types (prefer staying up late and waking up later). In a study of teens, Lee, McEnany, and Weekes (1999) found that teen girls woke up earlier, slept in later on the weekend, and consumed less caffeine than boys consume. Finally, a study conducted by Duffy et al. (2011) indicated that females possess a shorter circadian rhythm than males, with a duration that is slightly less than 24-hours long. However, the results of this study have not been independently corroborated.

It is possible that the reported differences in sleep between males and females may be attributed to hormonal differences. Baker and Driver (2007) reviewed literature prior to 2007 and concluded that the hormonal rhythms that influence the female menstrual cycle also exert pressure on the circadian rhythm via minor disruptions. Shechter and Boivin (2009) noted in their review that differences in the amount of stage N2 NREM sleep and the amount of REM sleep that adult women obtained at night coincided with the phase of the menstrual cycle during which they were sleeping. When combining these results with the knowledge that different types of sleep can affect the performance of different types of memory (Rauchs, et al., 2005), it is possible that there is a difference in female sleep requirements compared to their male counterparts. However, the extent to which these differences manifest themselves in terms of daily performance and the reason for why such differences exist remains undetermined.

D. NAPPING

While we generally think of sleep as occurring primarily at night, that is not the only time that humans sleep. Most new parents look forward to the time when their young children take afternoon naps. In some siesta cultures, it is traditional to allocate time each afternoon for additional sleep or rest. This section explores naps and their role in human sleep and performance.

A nap is generally defined as a short period of sleep that is usually taken during daylight hours. Although the desire to nap at any time can be driven by a lack of sleep during the previous night or nights (Dinges et al.,1997), there is also a naturally occurring low point in alertness or dip in the 24-hour circadian rhythm that occurs in the early afternoon (Aschoff, 1994). This natural dip can contribute to any lingering feelings of tiredness from the previous night or nights, resulting in a heightened desire to take a nap during the time-period overlapping the circadian dip ("Sleep Drive," 2018).

1. Benefits

Research findings on the benefits of napping are almost exclusively positive in nature. Even in periods of long-term sleep deprivation, the addition of a nap has been shown to mitigate the decrease in performance associated with a lack of sleep (Dinges, Whitehouse, Orne, & Orne, 1988; Dinges, Orne, Orne, & Whitehouse, 1986). It also has been noted that naps which occur prior to sleep loss (so called prophylactic naps), lead to better performance of a task than naps that occurred after sleep loss (Dinges, Orne, Whitehouse & Orne, 1987). Interestingly, naps occurring early in the Dinges et al. (1987) experiment happened before the participants were feeling tired but led to some of the best performance on the assigned task. It is likely that naps, while excellent at preventing sleepiness and promoting gains in short term alertness, might not be the best means of recovering sleep that has been lost (Dinges et al., 1987). Finally, naps taken even when participants obtained their normal amount of sleep the night prior, resulted in performance improvements (Lau, Wong, Lau, Hui, & Tseng, 2015), inferring that even when there is no sleep debt involved, a nap can still prove beneficial to performance. These results indicate that naps can provide added benefits to learning and performance, both when sleep has been curtailed from desired levels, and when it has not.

2. Optimal Length

The optimal nap length necessary to counteract feelings of fatigue or sleepiness has been the subject of intense scrutiny. Individuals who are deprived of sleep for a full night or more benefit the most from a longer nap versus a shorter one (Helmus et al., 1997; Dinges et al., 1987). However, time for a longer nap is not always available or feasible in today's busy world. Hayashi, Motoyashi, and Hori (2005) determined participants whose naps included at least a few minutes of stage N2 NREM sleep had better alertness and performance than those who had no nap or whose sleep stages only consisted of N1 sleep. The results from Hayashi et al. (2005) indicated that stage N2 sleep was reached on average nine minutes after starting to sleep.

Brooks and Lack (2006) extended Hayashi's findings and compared the performance of participants who took 5, 10, 20, and 30-minute naps to those who did not take a nap at all. Their results indicated that the 10-minute nap provided the longest duration of performance improvement while at the same time avoiding the effects of sleep inertia, a condition that had a detrimental effect on the performance of those who took longer naps. Of note, their participants were not carrying a large sleep debt. The endorsement of a 10-minute nap confirms the usefulness of the so-called power nap," which has been widely touted as extremely beneficial. However, it is likely that the Brooks and Lack (2006) findings only apply to nappers who obtain acceptable amounts of daily sleep prior to taking a nap.

In their study exploring the reaction times of participants who only received four hours of sleep at night, Gillberg, Kecklund, Axelsson, and Akerstedt (1996) found that a 30-minute nap restored reaction times back to baseline (which was measured at 7.5 hours of sleep at night), but only for a brief period of time. A study by Doran, Van Dongen and Dinges (2001) indicated that a 2-hour nap resulted in only minor degradation of performance during a 90-hour sleep deprivation period. However, it must be noted that the participants in the Gillberg et al. (1996) study were required to obtain a normal amount of sleep in the nights prior to the experiment, and only operated on sleep deprivation levels for two days. Likewise, the participants in the Doran et al. (2001) study were required to sleep at least eight hours of sleep each night in the week prior to the experiment, a luxury not often available to the general population.

E. SLEEP INERTIA

Sleep inertia is described as a period of confusion or lethargy that occurs when one is awakened from deep stages sleep. Sleep inertia happens most recognizably after long duration naps due to the deeper sleep stages that occur during long naps (Tassi & Muzet, 2000). As noted in the results of the Brooks and Lack (2006) study, sleep inertia affects the performance of reaction time tasks for varying time periods after awakening from a nap. Sleep inertia also occurs after awakening from a normal sleep period but appears to dissipate almost entirely within two hours following awakening (Jewett et al., 1999). The dissipation of sleep inertia and its effect on sleepiness and cognitive function appear to follow a roughly exponential curve over time (Jewett et al., 1999). This curve is illustrated in Figure 5. The top graph (a) depicts participants' increasing levels of alertness over time and as sleep inertia dissipates. The bottom graph (b) depicts participants' increasing ability to complete cognitive tasks as sleep inertia dissipates. Both graphs indicate that sleep inertia has mostly dissipated by approximately two hours after awakening. The conclusion derived from these studies is that sleep inertia can cause decreases in performance until it dissipates and should be avoided by careful planning if one wishes to avoid degraded performance outcomes.

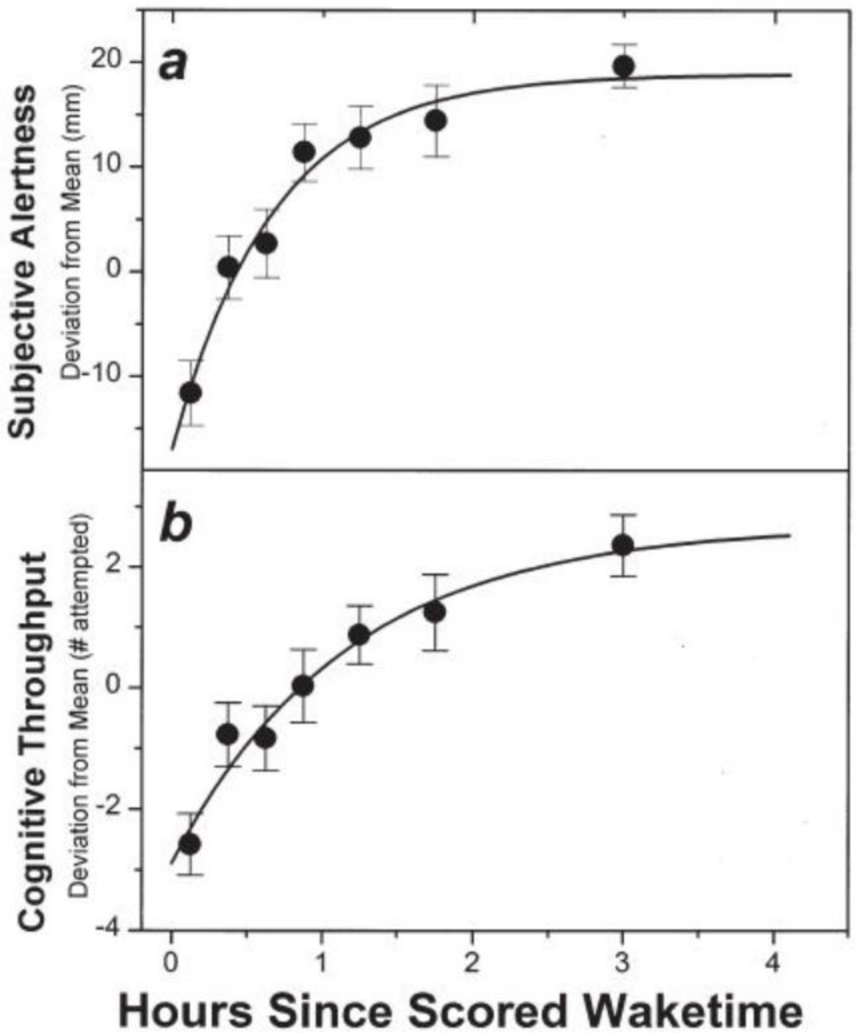

Figure 5. Exponential dissipation of sleep inertia over time on (a) alertness results, measured subjectively and showing an increase in alertness as sleep inertia dissipates; (b) results from a cognitive test, showing that cognitive ability increases as sleep inertia dissipates. Source: Jewett et al. (1999).

F. CAUSES OF INSOMNIA

While there are many unique causes for inability to fall sleep, this section explores a few of the possible non-medical reasons. The phase shift in circadian rhythm that occurs at the onset of puberty and its effect on the teen and young adult sleeping cycles has already been discussed. Other reasons will be explored here.

1. Circadian Chronotype or Morningness-Eveningness Preference

The circadian rhythm of most adults can be classified based on their circadian chronotype or general preference for morning or evening activities. A self-assessed questionnaire can be taken which divides individual into one of three groups: the morning-type who goes to bed early and wakes up in the early morning, the evening-type who prefers to go to bed later at night and wake up later the next morning, or the intermediate-type who falls between the two previous extremes and generally retires at a moderate hour and wakes up at a reasonable time (Horne & Ostberg, 1976). This natural preference corresponds with an individual's circadian rhythm (Mongrain, Lavoie, Selmaoui, Paquet & Dumont, 2004) and has the ability to influence a person's desired sleeping pattern, such as one necessary for a job or school. Chronotype influences the preferred timing of night sleep but not necessarily the duration. Study results have indicated a preference in males for later bedtimes (Mongrain et al., 2004), regardless of chronotype, when compared with female bedtime preferences (Adnan & Natale, 2002). Thus, a person's chronotype may interact with the ability to sleep by affecting sleep duration through an individual's inability to sleep at the beginning of a sleep period, or fall back asleep close to the end of a desired sleep period.

2. Caffeine

Caffeine is a well-known and frequently used stimulant, as evidenced by the over 8 million estimated cups of coffee that Starbucks alone serves around the world daily (Qin, 2018, para. 12). In a study comparing the effects of eating breakfast or having caffeine on cognitive performance and mood, Smith, Kendrick, Maben & Salmon (1994) found that participants who received caffeine in the morning exhibited better performance on all cognitive tasks, while breakfast consumers only improved in some of the cognitive tasks. A review of caffeine's effect on both mental and physical functions, conducted by McLellan, Caldwell, and Lieberman (2016) found that moderate doses of caffeine improved alertness, ability to learn, and mood, both in subjects who were sleep-deprived and in those who were not. The positive effect of caffeine consumption can be observed in Figure 6, which compares caffeine consumption and non-consumption for both reaction times (A) and the number of correct visual identifications on a cognitive test (B). McLellan et al. (2016) found that moderate caffeine consumption improved physical performance, as well.

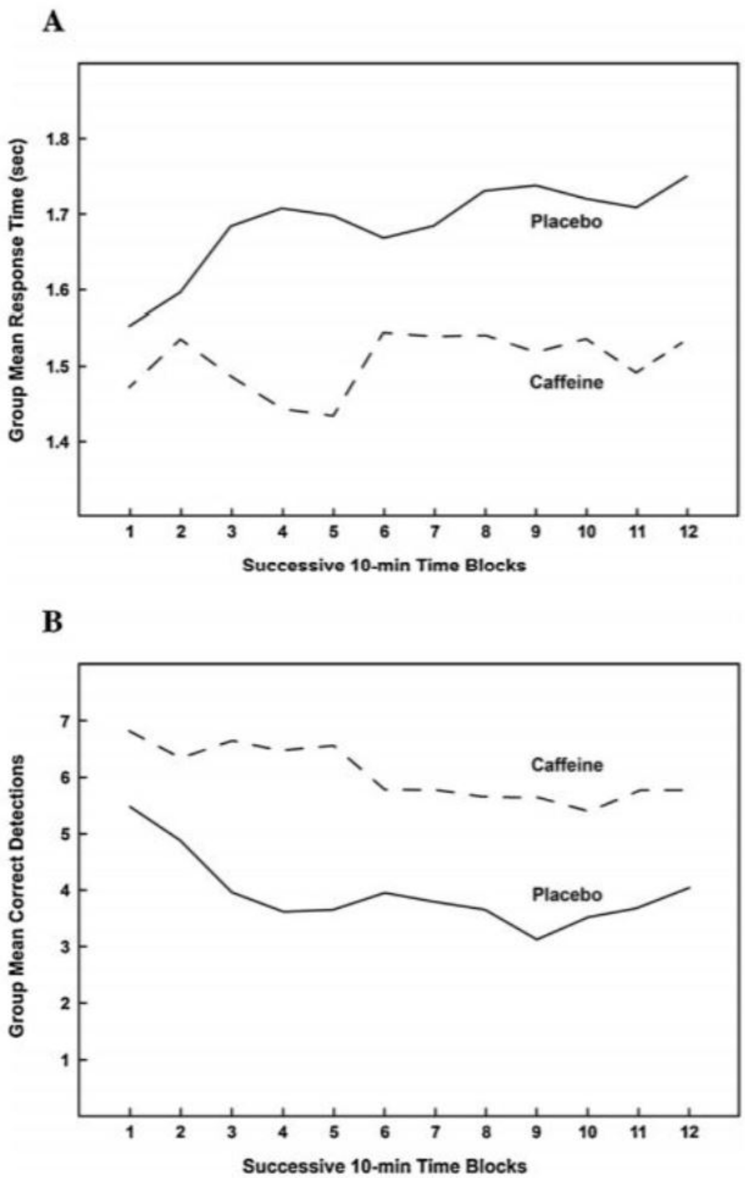

Figure 6. Graphs depicting the superior performance of participants given caffeine on two different tests over a two-hour period: (a) Reaction time test; (b) Visual test for number of correct detections. Participants given caffeine were more successful on both tests. Source: Fine et al. (1994).

While the studies mentioned indicate positive effects of caffeine consumption, research also indicates that caffeine can have negative consequences, especially if consumed at the wrong time of day or in the wrong amounts. Karacan et al. (1976) found that caffeine consumption before bed effectively mimicked insomnia symptoms (i.e., difficulty falling asleep) in participants and shifted their sleep stages. Lin, Uhde, Slate, & McCann (1997) found that low doses of caffeine given to test subjects while they slept resulted in disrupted sleep and elevated levels of the stress hormone cortisol, indicating that even lingering amounts of caffeine in the body can affect the sleep cycle. Chaudhary, Grandner, Jackson, and Chakravorty (2016) used the results of a national nutritional survey to execute a logistic regression exploring the relationships between caffeine, insomnia and sleep duration. They found a relationship between caffeine consumption and low sleep duration, indicating that caffeine consumption could result in poor sleep quality. A study of college students conducted by Hicks, Hicks, Reyes, and Cheers (1983) also indicated that increasing amounts of caffeine consumption resulted in less nightly sleep. Both results indicate the existence of a vicious cycle of poor sleep, the effects of which are subsequently masked by caffeine consumption, only to result in more poor sleep. Therefore, while caffeine may be helpful on occasion, it is highly likely that its increased use throughout the day, coupled with sleep deprivation, may be detrimental to obtaining good quality sleep.

3. Stress

Cortisol was identified earlier as one of the biological indicators of the circadian rhythm. However, cortisol is also known as the “stress hormone” for its increased presence when faced with a stressful response. (“What is cortisol,” 2018). It is fair to conclude that stress can have a deleterious effect on sleep quality and quantity. Akerstedt, Kecklund, and Axelsson (2007) compared sleep that occurred during low, intermediate, and high stress days, with the stress levels rated by the study participants. Their results indicate that normal sleep patterns were delayed, and participants had a lower sleep efficiency (defined as the amount of time asleep, divided by the total time a participant was both attempting to sleep and actually sleeping) on both intermediate and high stress days, although sleep was less impaired on the intermediate stress days. Brown, Buboltz, and Soper (2010) found that worrying while attempting to fall asleep was one of the four main factors predicting sleep quality. Amara et al. (2018) also found that stress increased sleep difficulties in college students. In addition, they reported differences in the effect of stress on male versus female participants, with female students reporting more difficulties than males. Considering the pressure that most college students are under, it is reasonable that stress could be contributing to a general lack of sleep in the college population.

4. Melatonin

Like cortisol, melatonin plays a significant role in the circadian rhythm and the timing of sleep. Melatonin is primarily created and released by the pineal gland, located deep in the brain; its secretion generally follows the body's circadian rhythm ("Melatonin," 2018). However, melatonin production can be affected by the amount of light, especially blue light, to which a person is exposed. Experiments have shown that while light of all wavelengths affects melatonin secretion to varying amounts, wavelengths which appear to the human eye as the color blue produce the greatest melatonin suppression (West et al., 2011). Humans are surrounded by considerable amounts of blue light. In addition to the sun, blue light is also emitted from fluorescent and LED lighting, as well as digital devices such as laptops, cellphones, and television screens ("Blue light exposed," 2018). Crowley, Cain, Burns, Acebo, and Carskadon (2015) found that melatonin levels were suppressed (indicating a delay in sleepiness in the circadian rhythm) significantly in pre-pubertal school age children who were exposed to blue light, as compared to pubertal teenagers where suppression occurred to a lesser amount. This result both highlights the sensitivity of the melatonin cycle to light and demonstrates the effect of light on melatonin secretion in school-age children and teens (Crowley et al., 2015). This result is concerning, however, because it indicates that blue-light exposure is especially impactful to the circadian rhythm in children.

Based on the recent trend of using digital devices in the evening hours for relaxation purposes, it is not surprising that the devices may contribute to a lack of sleep in young adults and adults. Arora, Broglia, Thomas, and Taheri (2013) determined through survey responses of teens that increasing time spent using any technology resulted in less sleep during the weekdays. However, young teens who watched television experienced the greatest loss of sleep. Respondents who used their phone, played video games, spent time on their social networks, and listened to music also reported difficulty falling asleep (Arora et al., 2013). Although not explicitly stated in the survey, it is likely that the difficulty in falling asleep was partially related to melatonin suppression from blue light exposure.

In a study of first-year college students, Orzech, Grandner, Roane, and Carskadon (2016) analyzed self-reported sleep outcomes and digital media usage of participants in the two hours prior to sleep. Students who spent more time using digital devices both went to bed later and reported less sleep time (Orzech et al., 2016). A study completed by Murdoch, Adams, Crichlow-Ball, Horissian, and Roberts (2017) investigated cellphone use and its effect on sleep. Murdoch et al. (2017) found that both nighttime cellphone notifications and students' compulsion to check their cellphones both predicted problems sleeping and the amount of sleepiness the students reported.

The factors explored above demonstrate how sleep can be affected and altered by human choices. But they also provide a path toward better sleep. Avoiding or limiting daily caffeine intake is likely to increase the duration and quality of sleep. Stress may be unavoidable, but there are methods that can be used to quiet the mind and decrease feelings of stress, thereby reducing cortisol prior to sleep. But for optimal sleep, it appears critical for humans to avoid lengthy exposure to blue light by limiting their use of digital devices and television prior to sleep or by changing the settings of their devices to block blue light in the evening hours prior to bedtime. Following these measures is a step in the right direction toward better sleep.

G. QUANTIFYING SLEEP

1. Polysomnography

The scientific standard for measuring and quantifying sleep is polysomnography (PSG). PSG combines the tracking of electrical events in the brain, eye movement, muscle activity, and heart rate while the subject sleeps ("Polysomnography," 2018). However, the equipment necessary to utilize and monitor the multiple components that comprise PSG recordings can only be used in a laboratory setting and requires human oversight. These factors mean that PSGs are too cumbersome for long-term studies or for monitoring large numbers of participants. It is for this reason that other methods have been explored and currently are in use.

2. Actigraphy

The miniaturization of monitoring and computational systems in the last few decades has led to the rise of actigraphy, where participants wear a small watch-like device that contains an accelerometer to continuously record the wearer's number of movements over time. The activity recordings are then transferred to a computer where an algorithm assists in determining sleep periods, which are characterized by reduced movement counts. For participants who experience normal sleep patterns and for a few specific types of sleep disorders, actigraphy has been found to produce results accurate enough to assist in both diagnosing those specific sleep disorders or for use in scientific experiments (Sadeh, Hauri, Kripke, and Lavie, 1995; Ancoli-Israel et al., 2003). The validity of actigraphic methods were further confirmed with the 2015 Publication of "The SBSM Guide to Actigraphy Monitoring: Clinical and Research Applications" (Ancoli-Israel et al., 2015). This guide reviewed all information pertaining to the collection of actigraphy data and provided standards by which actigraphy studies should be executed, as well as standards and recommendations as to the correct and accurate use of actigraphy devices (Ancoli-Israel et al., 2015). The guide has also contributed immensely to standardized actigraphy device usage. Actigraphy is used widely now in many sleep studies.

3. Activity Logs

A third method of tracking and quantifying sleep involves the use of sleep logs or activity logs. These logs are provided to study participants to track sleep information (estimated bedtime, awakening, etc.), and daily activities. The information from the log can then be utilized to determine sleep or activity patterns, confirm actigraphy-provided data, or to determine or verify a subject's sleep habits.

Utilization of a sleep log alone, while perhaps the easiest method to conduct a study, should be utilized with caution. McCall and McCall (2012), in addition to confirming the relative accuracy of actigraphy-collected sleep data, found that sleep log data were significantly different from both PSG and actigraphy-collected data in ways that made the sleep log data less accurate for diagnosing sleep disorders. Girshik, Fritschi, Heyworth, and Waters (2012) found that participants' self-reported daily sleep (i.e., asked as one question and not an actual log) was not an accurate representation of sleep when compared to the participant's actigraphic data. These results indicate that the accuracy of self-reported sleep data is not adequate for most scientific studies.

On the other hand, Junquist, Pender, Klingman, and Mund (2015) reported that when sleep study participants wore a digital device which contained self-initiated questions about the participant's sleep twice a day, the data collected by the digital device was only slightly different than that information collected by actigraphy and was generally as accurate as using a paper sleep log. Tonetti, Mingozzi, and Natale (2016) also confirmed that there was little difference between a paper sleep log and a digital sleep log. However, both studies noted that electronic sleep logs were much easier for analysis purposes and recommended that electronic sleep logs be utilized whenever possible (Jungquist et al., 2015; Tonetti et al., 2016). This recommendation contrasts with Ancoli-Israel et al. (2015) who recommended that paper logs be utilized, unless electronic sleep logs were created to complement the actigraphic method of collecting sleep data.

4. Precise Measurement of Sleep

In order to precisely track and quantify sleep, PSG is the standard to which all other measures are compared. It is the most accurate of all the sleep-tracking mechanisms (McCall and McCall, 2012). It is followed by actigraphy, which is generally accurate and has the added benefit of being not only much less expensive to perform, but also more feasible for long-term studies. Sleep or activity logs are the least preferred method of tracking and quantifying sleep due to their inconsistencies in accurately reporting results. It is highly recommended, however, that sleep logs be utilized in addition to actigraphy monitoring, for their ability to provide additional data that can aid in the interpretation of the actigraphic results (Ancoli-Israel et al., 2015).

H. PREVIOUS USMA CADET SLEEP STUDIES

Personal anecdotes from former graduates indicate that Cadets do not sleep much while attending the U.S. Military Academy. The results from a study in 2003 to 2007 conducted by Miller, Shattuck, and Matsangas (2010), confirmed this hypothesis. In a four-year longitudinal study conducted on the Class of 2007, they tracked the sleep and naps of a sample of 80 Cadets as they progressed through their entire four years at USMA. The Cadets wore wrist activity monitors (WAMs) and completed activity logs for one month during both fall and spring semesters of each year. The resulting sleep data were analyzed to provide insight into Cadet sleep habits.

Miller, Shattuck, and Matstangas' (2010) findings showed that both daily and nighttime sleep were associated with a Cadet's academic year, the semester of study, the season, Cadet gender, the type of day the sleep occurred on (either weekday or weekend), and the day of the week. The average daily sleep of Cadets in academic years 2005 through 2007 (daily sleep data was not available for year 2004) was 5.77 hours (Miller et al., 2010). Miller et al. (2010) also reported a trend of increasing Cadet daily sleep as Cadets progressed through the academic years of 2005 through 2007. Daily sleep increased by 0.20 hours (12 minutes) and 0.32 hours (19 minutes) respectively between the academic years (Miller et al., 2010). Further analysis indicated a consistent trend of Cadets obtaining more sleep in fall semesters than they did in the spring semesters of each academic year, with the exception of the Cadets' initial fall semester, which occurred in the fall of 2003. (Miller et al., 2010).

Miller, Shattuck, and Matstangas (2010) also reported that nighttime sleep had increased across the four academic years of the study. As in daily sleep, nighttime sleep durations exhibited the same pattern of a lower average sleep duration in the spring semester than in the fall semester (Miller et al., 2010). In their study, unlike the daily sleep analysis, nighttime sleep decreased in the fourth year. They suggest that this drop could be in response to the increased responsibility placed on fourth-year (senior) Cadets (Miller et al., 2010). In 2007, Cadets appear to compensate for the loss of nighttime sleep by taking more naps (Miller et al., 2010).

Miller, Shattuck, and Matsangas (2010) also reported a statistically significant difference in the amount of nighttime sleep that Cadets obtained on school nights (Sunday through Thursday nights and on weekend nights (Friday and Saturday nights). On school nights, Cadets slept an average of 5.05 hours (SD=1.03 hours), and on weekend nights

Cadets slept an average of 6.48 hours (SD=1.85 hours), an increase of approximately 1.4 hours of sleep from school night to weekend night.

A presentation given by Dr. Nita L. Shattuck and COL (ret) Larry G. Shattuck to the USMA Commandant, Brigadier General Caslan on October 6, 2006, reported the average nighttime sleep Cadets obtained in each semester, from fall 2003 through spring 2006 (the start of Plebe (freshman) year through the end of the Cow (junior) year of attendance). When the data was analyzed based on the day type in which the sleep occurred (school night or weekend night), Plebe Cadets slept an average of 4.88 hours on school nights and 6.87 hours on weekend nights in the fall semester (Miller & Shattuck, 2006). Yearling (sophomore) Cadets slept an average of 5.28 hours on school nights and 7.04 hours on weekend nights in the fall semester (Miller & Shattuck, 2006). Cow (junior) Cadets slept an average of 5.25 hours on school nights and 7.22 hours on weekend nights in the fall semester (Miller & Shattuck, 2006).

Finally, Miller, Shattuck and Matsangas (2010) found that female Cadets slept more than male Cadets. The average difference in daily sleep duration was approximately 0.38 hours (23 minutes) more sleep for female Cadets than male Cadets, with female Cadets sleeping an average of 6.04 hours daily and male Cadets sleeping an average of 5.68 hours daily (Miller et al., 2010). The trend remained the same for nighttime sleep, with female Cadets on average sleeping 0.35 hours (21 minutes) more at night than male Cadets (Miller et al., 2010). Female Cadets obtained significantly more sleep than male Cadets when results were calculated across the academic year, the semester, and the day of the week (Miller et al., 2010).

In his master's thesis, Miller (2005) studied the sleep duration of USMA Cadets in the Class of 2007 during their initial Cadet Basic Training (CBT) in summer 2003. Miller's results indicated that Cadets attending CBT slept an average of 5.7 hours at night, approximately 2.1 hours less sleep than the Cadets reported obtaining prior to attending CBT. Miller then conducted an analysis of the Cadets' predicted effectiveness using the SAFTE Model and Fatigue Avoidance Scheduling Tool (FAST) and determined that Cadets obtaining 5.7 hours of sleep were operating at approximately 84% effectiveness. Miller suggested allowing Cadets one extra hour of sleep (an increase to 6.7 hours of nighttime sleep) could increase Cadet effectiveness to an average of 90%, likely improving Cadet alertness and memory functions.

Kenney and Neverosky (2004) reported the sleep patterns of Cadets in the Class of 2007, based on data collected in the fall of 2003. They found that Cadets on average slept 4.8 hours on school nights and 6.6 hours on weekend nights. They also analyzed Cadet attrition based on the Cadets' morningness-eveningness preferences and found that Cadets who exhibited an eveningness preference withdrew from USMA at higher rates than Cadets who exhibited a morningness preference. Cadets who exhibited a morningness preference also exhibited better performance, as measured by the fall semester's academic GPA, military program score, and physical program score (Kenney & Neverosky, 2004).

Godfrey (2006) studied USMA Cadet napping patterns based on data collected from the Class of 2007 in the fall of 2004. Her research indicated Cadets took naps most frequently on weekdays, with nap frequency and duration being the greatest on Wednesdays. The average nap duration lasted between 0.5 and 1.5 hours, and Cadets napped in the afternoon more often than in the evening (Godfrey, 2006). Godfrey concluded that because Cadets did not sleep enough at night, their naps were restorative in nature and used as an attempt to counteract their constant sleep debt.

I. CURRENT HYPOTHESES

Of the many social and cultural changes that have occurred in the ten years since Miller, Shattuck and Matsangas (2010) conducted their longitudinal study, an obvious one has been the increased dependence on digital devices such as cellphones and computers. Given that previous studies have indicated electronic usage can have a detrimental effect on sleep duration (Arora, Broglia, Thomas, and Taheri, 2013) and the short sleep durations mentioned in the previous studies (Miller, Shattuck, & Matsangas, 2010; Kenney & Neverosky, 2004; Godfrey, 2006), the first hypothesis for this study was that nighttime sleep and daily sleep durations had either continued to decrease or remained similar to the 2003-2007 study. The second hypothesis was that both daily and nighttime sleep durations would continue to be associated with the academic year, gender, the type of day, and a Cadet's participation in Corps-Squad athletics, the latter of which was included as part of the present study at the behest of USMA leadership. The final hypothesis was that the availability and ease of use of the digital activity log would yield a more accurate estimate of sleep duration when the duration was compared to actigraphic results.

III. METHOD

The purpose of this thesis is to compare the daily activities and sleep patterns of 269 U.S. Military Academy Cadets from four different year groups during the fall semester of 2017 to the results from a four-year longitudinal study of the Class of 2007, as reported by Miller, Shattuck, and Matsangas (2010). It analyzes sleep durations to determine whether significant differences between the male and female Cadets still exist. It also explores the napping patterns of Cadets. Finally, by using participants' activity logs, this thesis explores how Cadets are utilizing their time while studying at USMA.

The data utilized for these analyses was extracted from the first half of a yearlong study commissioned by USMA. Participants completed a questionnaire that gathered demographic data as well as information about their current sleep habits before receiving a wrist activity monitor (WAM) and a user-name and password to a web-based activity log application (app), which was used to track the participants' daily activities and each activity's duration. After wearing the watch for approximately two weeks, the actigraphy data were downloaded and the results were compared to the participants' app entries to verify the accuracy of the data. The resulting actigraphy information was then exported into Excel and average daily and nighttime sleep amounts and nap durations were calculated for each participant. These results were stratified by day of the week or day type, year group, gender, or participation in Corps Squad athletics when indicated, for comparison to the results of the 2007 study. Additional analysis was conducted on a subset of 31 participants with app entries indicative of full compliance, to determine the Cadets' time utilization and to compare self-reported sleep results with actigraphic sleep results.

A. PARTICIPANTS

Two hundred sixty-nine Cadets, from the year groups graduating in 2018, 2019, 2020, and 2021 participated in this study. A table of the demographics of each class can be observed in Table 1. For comparison, Table 2 contains a breakdown of the demographics of Cadets who participated in the current sleep study. USMA reported a gender breakdown of 78% male and 22% female Cadets, with 92% of attendees being between the ages of

19–23. The gender composition of sleep study participants was 65% male and 35% female; female Cadets were purposely oversampled for statistical purposes. In addition to the typical demographics, this study also collected information on which participants were Corps Squad athletes. Approximately 18% (48 participants) of the sleep study participants were Corps Squad athletes, and their breakdown by gender and year group can be observed in Table 3. The Corps Squad athlete study participants were 56% male and 44% female. Six Corps Squad athletes (1 female Cadet from year group 2021, 2 female Cadets from year group 2020, and 1 female and 2 male Cadets from year group 2018) were not actively competing in their sport during the data collection period. A count of the total number of Corps Squad athletes currently attending USMA was not available. Excluding the necessary oversampling of female Cadets, it was noted that the study sample was generally consistent with the demographics of the USMA population.

Table 1. Demographics of all Cadets currently attending USMA.

USMA DEMOGRAPHICS				
Year Group	**Number of Cadets**	**Percent of Participants**	**Gender**	**Percent of Year Group**
2021 (Plebe)	1206	26%	Male: 915	76%
			Female: 291	24%
2020 (Yearling)	1215	27%	Male: 951	78%
			Female: 264	22%
2019 (Cow)	1087	24%	Male: 849	78%
			Female: 238	22%
2018 (Firstie)	1035	23%	Male: 830	80%
			Female: 205	20%

Table 2. Demographics of sleep study participants.

SLEEP STUDY DEMOGRAPHICS					
Year Group	Number of Cadets	Percent of Participants	Gender	Percent of Year Group	Age Range
2021 (Plebe)	91	34%	Male: 61	67%	17-23
			Female: 30	33%	
2020 (Yearling)	70	26%	Male: 45	64%	18-23
			Female: 25	36%	
2019 (Cow)	49	18%	Male: 31	63%	18-24
			Female: 18	37%	
2018 (Firstie)	59	22%	Male: 37	63%	20-26
			Female: 22	37%	

Table 3. Demographics of study participants who are also Corps Squad athletes.

ATHLETE DEMOGRAPHICS (SLEEP STUDY)				
Year Group	Number of Athletes	Percent of Athletes	Gender	Percent of Year Group
2021 (Plebe)	16	33%	Male: 8	50%
			Female: 8	50%
2020 (Yearling)	12	25%	Male: 9	75%
			Female: 3	25%
2019 (Cow)	10	21%	Male: 6	60%
			Female: 4	40%
2018 (Firstie)	10	21%	Male: 4	40%
			Female: 6	60%

Unlike the typical college selection process, admission to USMA is a rigorous process that requires not only academic achievement but also physical fitness, mental toughness, and demonstrated leadership capabilities. Cadets must remain in excellent physical health while attending West Point, and as a result generally are not prone to mental and physical issues. USMA Cadets also follow a daily schedule throughout all four years of their attendance at West Point. This requirement results in much less daily free time than the typical college student. An example of the general weekday and weekend schedule for all Cadets can be seen in Figure 7. Free time is the least for Plebe Cadets (year group 2021), who have more mandatory events than the other year groups. The amount of free time generally increases as Cadets advance in the Cadet hierarchy. Actual Cadet timelines vary based on the requirements of each Cadet's academic major. Not listed on the schedules are the various military duties that each Cadet must take care of weekly such as maintaining the required uniforms, preparing for military events, Cadet leadership requirements (especially for the Cadets in their final year), and other requirements that military customs and training demand. It is possible that these requirements influence the amount of sleep Cadets obtain.

WEEKDAYS		
Morning:	0655	Mandatory morning formation
	0655-0730	Breakfast (mandatory for Plebes daily; mandatory on Thursday for all year groups)
	0730-1145	Classes or study time. Classes run in 55 minute periods with a 15-minute passing period between classes.
Afternoon:	1205	Lunch formation (mandatory)
	1205-1230	Lunch
	1245-1340	Dean/Commondant time (can be used for study)
	1355-1600	Classes
	1630-1830	Athletics practice. Varies in time/day for Corps-Squad Athletes versus Club or Company Level.
Evening:	1800-1930	Supper served (attendance not mandatory)
	1930-2330	Evening Study Period (no activities scheduled); Cadets may use the time as desired.

SATURDAY		
Morning:	0530-1130	Mandatory event attendance: football game, parade, military training, etc. Actual start time may vary, but all Cadets are released by 1130.

Figure 7. General weekly schedule of all Cadets attending USMA.

B. PROCEDURES

Cadets were recruited via email and in-person recruitment was conducted at various locations across the USMA campus. Once Cadets consented to participate, they were asked to complete questionnaires gathering demographic data and self-reported information on the Cadets' sleep habits: the Epworth Sleepiness Scale, the Pittsburgh Sleep Quality Index (PSQI), and the Morningness-Eveningness Questionnaire. These questionnaires are designed to gather information on actions, which may influence a participant's sleep duration and sleep quality. Participating Cadets were also issued a WAM, which they were instructed to wear on their non-dominant arm for the duration of the study. In addition to wearing the WAM, participants were also provided a user log-in and password to the app where they were instructed to fill out a daily activity log. The activity log is valuable for verifying sleep periods, especially naps, which are not always easily distinguishable based on the WAM. The activity logs in this study were critical in providing information on Cadet time utilization.

For the fall 2017 portion of the study, WAMs were issued 19–25 October; all WAMs were returned 6–7 November 2017. In total, 269 Cadets participated in the study, and a subset of 31 activity logs were utilized for additional analyses. Once returned to the experimenters, each WAM was downloaded, individually compared to the app results when possible, and then analyzed using sleep analysis software to determine the sleep periods detected by each WAM.

The WAM sleep periods were divided into three different sleep types: daily sleep, nighttime sleep, and naps. Daily sleep is defined as the total amount of sleep and naps that a participant obtains over a 24-hour period. Nighttime sleep is defined as the total amount of sleep that occurs during the evening hours, loosely defined in this study as occurring from 8:00 PM one evening until awakening the next morning. Naps are defined as sleep that both begins and ends within the same day and occurs anytime from the mid-morning through approximately 8:00 PM in the evening. Each of the three sleep types was further divided into sleep that affected school days and sleep that affected weekends. This was necessary due to statistically significant differences in sleep duration that occurred on school days and nights, compared to sleep durations that occurred on weekend days and nights. Each sleep period was additionally credited toward the day of the week that the sleep would have most likely affected. Therefore, a nap taken on Sunday afternoon was credited as part of Sunday's sleep accumulation. For example, a sleep episode occurring from 11:00 PM on Sunday through 5:30 AM on Monday was credited as being part of Monday's sleep accumulation. School day sleep periods were therefore calculated as sleep credited toward Monday, Tuesday, Wednesday, Thursday, or Friday; weekend sleep periods were those calculated as affecting Saturday and Sunday.

Each participant in the three sleep types (daily, nighttime, and naps) was individually analyzed to provide an average amount of sleep and standard deviation for each type of day (school day and weekend). These results then were combined to calculate an overall average duration and standard deviation for each type of sleep, for each type of day. The participants in each sleep type were further divided into groups according to gender, year group, and athletic status as necessary for analysis. Average sleep amount with standard deviation was calculated for each sub-group as needed.

The analysis of the app data was conducted in a different manner due to the need for complete (or almost complete) app participation. Participants were scored on the completeness of their app entries over the stretch of days that they completed them, as well as the interval between the end of a 24-hour period and the time the participant completed the activity log entries for that period. Only participants whose completeness surpassed 95% and who updated their app entries in three days or less were utilized in the analysis. These stringent requirements resulted in only 31 apps being deemed accurate enough to include in the analysis. An example layout of the app data is provided in Figure 8.

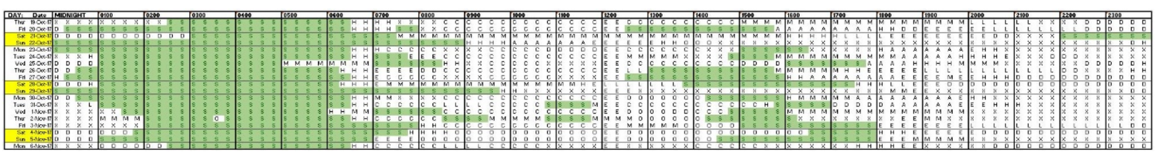

Figure 8. Layout of one participant's activity log data, with sleep periods highlighted in green and weekends highlighted in yellow.

C. APPARATUS

1. Hardware

a. Actiwatch or Wrist Activity Monitor (WAM)

Study participants were issued one of two different versions of an Actiwatch, both of which are manufactured by the Philips Respironics company. These WAMs (also called actigraphs or "sleep watches") are a square, watch-sized device that is strapped to the participants' wrist using a watchband. The WAM's purpose is to collect data on the movement of the participant, with the understanding that humans naturally move less during periods of sleep. WAMs have been found to be an effective, non-invasive method of monitoring sleep cycles in humans (Ancoli-Israel et al., 2003). Each WAM contains an accelerometer that measures the strength of an individual's movement, a sensor to determine whether the watch is being worn (or touching the skin), and a sensor that can detect various wavelengths of light, provided that the watch is not being covered by clothing. The WAMs were programmed to sample movement in 1-minute intervals, providing approximately 1,440 data points for each full day the WAM was worn.

b. Activity Log

Activity logs are frequently used in actigraphic sleep research. Because researchers cannot individually observe the participants each day, these logs provide an accounting of the participants' activities and can assist greatly in determining sleep episodes during times when the actigraphic data are not entirely clear, such as in short duration naps. Unlike in previous studies where a paper activity log was issued to participants, for this study a digital application (app) was created and hosted on a Naval Postgraduate School server, through which participants could quickly and easily annotate their daily activities in 15-minute intervals using a series of drop-down boxes. The layout and method of data entry for the app can be observed in Figure 9. For ease of use, the number of possible pre-programmed activities was limited to ten (Athletic, Class, Hygiene, LeisureDigital, LeisureNonDigital, Meal, MilitaryDuties, Other, SleepOrNap or Study), although an optional comment box was included for each activity to allow participants to note more specific information if desired. Each study participant was issued an individual log-in and password, ensuring that only the participant could enter data in the app. Compliance with the requirement to fill out the app daily varied greatly among participants with approximately 55% (147 out of 269) providing app entries for at least a portion of the days they wore the WAM.

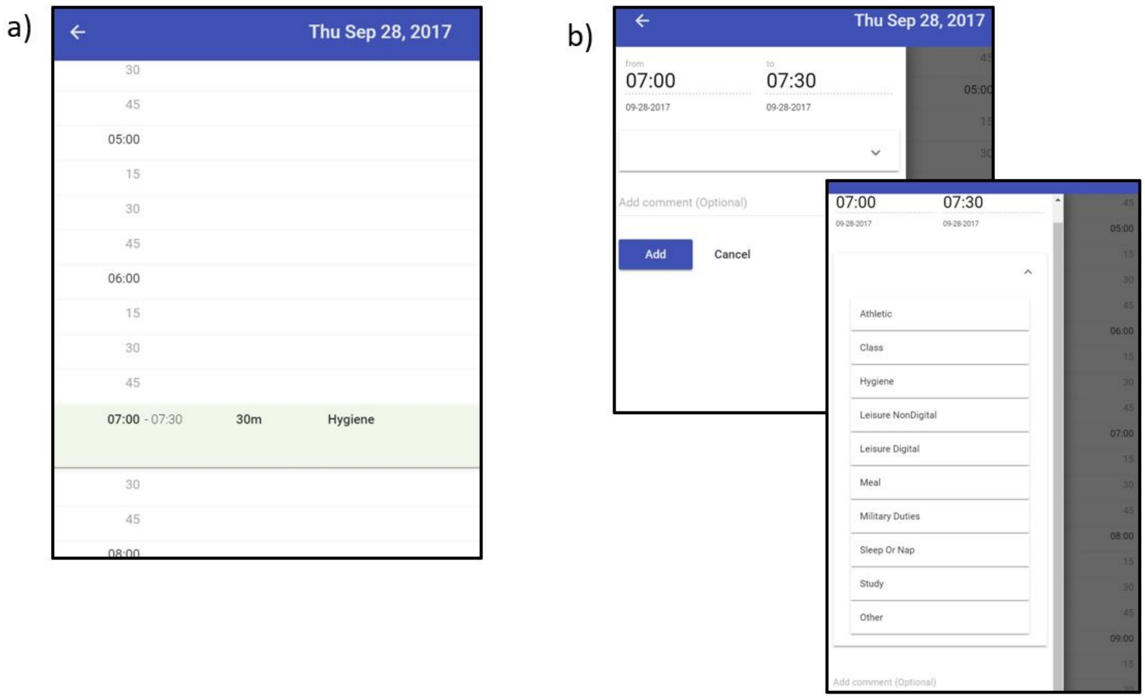

Figure 9. Screenshots of the app provided to participants: (a) What the app looks like after data entry; (b) The method of data entry and the choice of activities.

c. Questionnaires

Participants were asked to complete a pre-study questionnaire that included typical demographic information (age, gender, graduating class, etc.) as well as questions pertaining to the participants' lifestyle (smoking, exercise, etc.) and what factors affect their sleep. Participants also completed the Fatigue Severity Scale (FSS), the results of which can be used to determine the general sleepiness of an individual; the Pittsburgh Sleep Quality Index (PSQI), to determine the participants' sleep history; the Morningness-Eveningness Questionnaire, to determine their chronotype; and the Epworth Sleepiness Scale, to determine their current fatigue severity. Although the results of these sleep questionnaires were not utilized in this thesis, they will be utilized in the future to provide information about the sleep quality of Cadets.

2. Software

a. Actiware

Each WAM was downloaded and analyzed using the Philips Respironics Actiware Software Program, Version 6.0.9. The Actiware program contains an algorithm designed to assist in identifying periods of sleep, based on the data collected by the WAM. However, the algorithm is not always accurate in determining sleep episodes, especially intervals that are of short duration. Conveniently, the Actiware program allows for manual addition and manipulation of sleep episodes, allowing the researcher to review the data, compare it to an activity log when possible, and then manually annotate sleep episodes where they are deemed appropriate. Because of the subjectivity of analysis conducted in this manner, each actigram was reviewed by two separate researchers prior to conducting data analysis. Once the review was complete, the Actiware algorithm was utilized to calculate the duration of each sleep episode. The results were then exported to a Microsoft Excel file for further analysis.

b. JMP Pro

The distribution graphics created in support of this thesis were conducted using JMP Pro software, version 13.1.0.

c. Microsoft Excel

The calculations executed for this thesis were primarily conducted using Microsoft Excel 365.

d. Python

The Python programming language, version 3.5.2, was also utilized for calculations and for limited cleaning and combining of the data.

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IV. RESULTS

This section presents the results from analyses conducted on the actigraphy (sleep) and activity log data collected from USMA Cadets over approximately two weeks in October 2017. The results are broken into four sections based on the type of sleep or activity that was analyzed: daily sleep, nighttime sleep, naps, and activity log results. The daily sleep section provides the results of analyses conducted on the total amount of sleep and naps that Cadets obtained over a 24-hour period. The nighttime sleep section provides the results of analyses conducted on the amount of sleep that Cadets obtained from 8:00 PM one night through their awakening the following morning. The nap section provides the results of analyses conducted on the total duration of sleep (naps) the Cadets obtained from approximately 6:30AM through 8PM the same day. Finally, the activity log section provides information on how Cadets reported spending their time during the sleep study. Unless otherwise mentioned, diagnostic residual plots for fixed and mixed effects analysis of variance models meet all model assumptions.

A. DAILY SLEEP

A total of 269 Cadets provided data for the daily sleep analysis. Based on the research of Miller, Shattuck and Matsangas (2010), who reported that day of the week was a significant predictor of Cadet sleep duration, the average amount of daily sleep attributed to each day of the week was calculated first. The average, standard deviation, and median (all in hours), as well as the number of participants for each day, can be observed in Table 4. A graph of the average daily sleep duration can be seen in Figure 10. The graph indicates a trend of increasing daily sleep duration as the week progresses.

Table 4. The daily sleep (in hours) obtained by participants, according to the day of the week.

	Day of Week						
(in hours)	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Average	5.15	5.70	5.74	5.64	5.83	6.97	8.06
SD	1.09	1.11	1.16	1.12	1.17	1.60	1.35
Median	5.20	5.72	5.65	5.71	5.82	6.92	8.08
n (Participants)	258	258	262	264	267	260	250

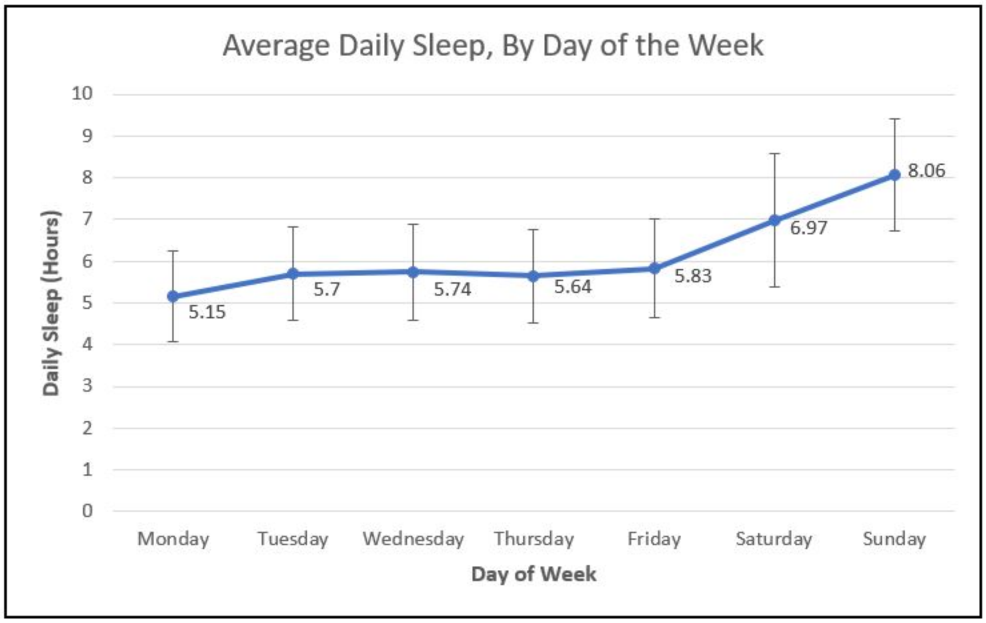

Figure 10. The average amount of daily sleep obtained on each day of the week, with standard deviation annotated.

To explore whether a trend was present and statistically significant, a mixed-effects analysis was conducted to determine which, if any, fixed effects from among year group, gender, day type, and Corps Squad athletic participation, accounted for significant variability in the daily sleep durations. In simplifying the analysis process, the days of the week predictor was recoded into a “day type” factor containing two levels: school days and weekends. A verification of the assumptions necessary for a linear model resulted in a lack of homoscedasticity in the residuals for predicting daily sleep duration. A log-transformation of the average daily sleep duration was necessary to stabilize the variance and induce homoscedasticity. A model, including interactions among the predictors, was then fit. The dependent variable for the mixed-effect analysis was the logarithm of the average daily duration of sleep per participant, and the random effect was the participants. Further experimentation resulted in the removal of the interaction terms, leaving only the four primary predictors as part of the model. Of those four predictors, three were found to be statistically significant within the model: year group (F-statistic, $F_{3,258} = 4.32$, p-value (p) = 0.005), gender ($F_{1,258} = 9.13$, $p = 0.003$), and day type ($F_{1,263} = 563.43$, $p < 0.001$). Corps Squad athletic participation did not contribute significantly to explaining the variance in sleep duration. Because of the difference between daily sleep duration on school days versus that of weekends, it was decided to conduct further analyses based on the type of day in which the daily sleep occurred (school day or weekend).

1. School Days

To determine the distribution of sleep duration on school days and nights, the average total duration of sleep and naps obtained on school days and school nights was calculated for each participant. The resulting distribution is shown in Figure 11. A one-sample Kolmogorov-Smirnov test, with test statistic D, was conducted to determine whether the daily sleep duration on school days was normally distributed. The test failed to reject the null hypothesis of a normal distribution ($D = 0.032$, $p = 0.9458$, $n = 269$), indicating that an assumption of normality was plausible. The average daily sleep that Cadets obtained during school days and nights was 5.61 hours (5 hours, 37 minutes) with a standard deviation (SD) of 0.72 hours (43 minutes). The median of the sample was 5.66 hours (5 hours, 40 minutes).

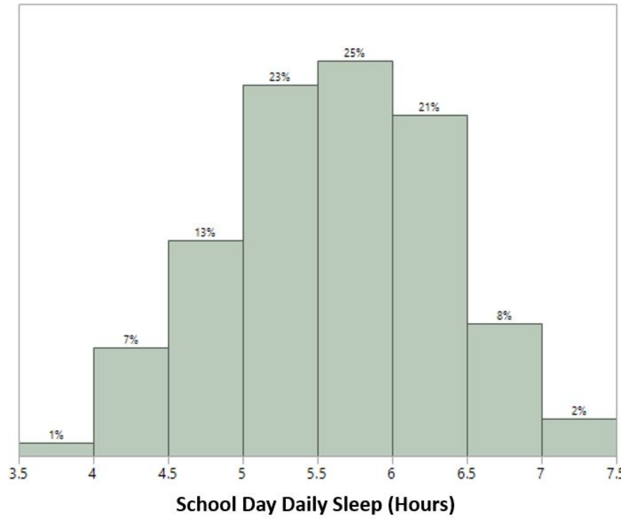

Figure 11. Distribution of average daily sleep duration for school days and school nights combined.

An analysis of variance (ANOVA) was conducted to determine whether year group, gender, and participation in Corps Squad athletics affected Cadets' school day daily sleep duration. Only gender emerged as having a statistically significant effect on school day daily sleep duration ($F_{1,268}$=6.49 p=0.00114). The difference in average daily sleep obtained between the genders on school days and nights can be seen in Figure 12. On average, female Cadets slept 5.76 hours daily (5 hours and 46 minutes, SD=0.68, n=95) while male Cadets on average slept 5.53 hours daily (5 hours and 32 minutes, SD=0.73, n=174). The difference in sleep was approximately 0.23 hours (14 minutes, standard error (se) = 0.08 hours), with female Cadets on average sleeping more on school days than their male peers.

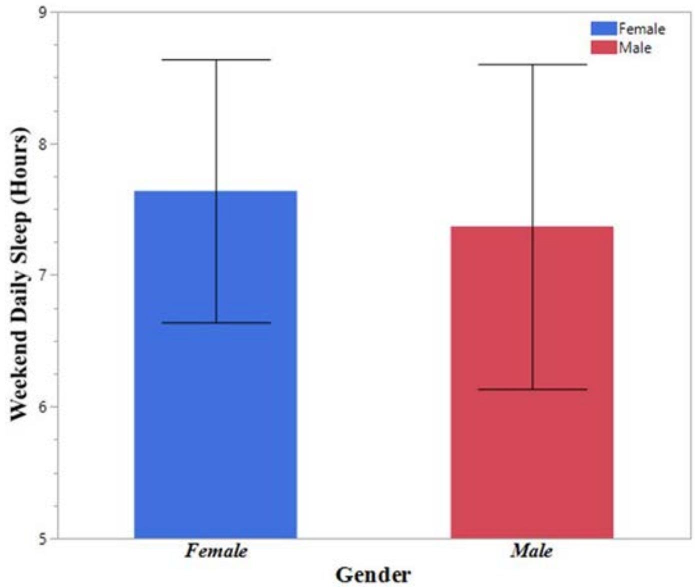

Figure 12. Average daily sleep obtained on weekend days and nights stratified by gender, with standard deviation annotated.

2. Weekends

Two hundred sixty-four Cadets provided sleep and nap data from Friday night through early Sunday evening for the weekend daily sleep duration analysis. The distribution of average weekend sleep and nap durations can be observed in Figure 13. A one-sample Kolmogorov-Smirnov test failed to reject the null hypothesis of a normal distribution ($D=0.050$, $p=0.527$, $n=264$), indicating that daily sleep on weekends could be normally distributed. The average daily sleep that Cadets obtained during the weekend was 7.47 hours (7 hours, 28 minutes) with a standard deviation of 1.16 hours (1 hour, 10 minutes). The median of the sample was 7.46 hours (7 hours, 28 minutes). The results from a large sample one-sided paired z-test indicated that the expected daily sleep duration on school days and school nights was significantly less than the expected daily sleep duration on weekend days and weekend nights ($z = 23.932$, $p < 0.001$, $n=264$). Cadets slept on average 1.85 hours (1 hour and 51 minutes, $SD = 1.25$ hours, $se = 0.08$ hours) more on weekend days and nights than on school days and nights.

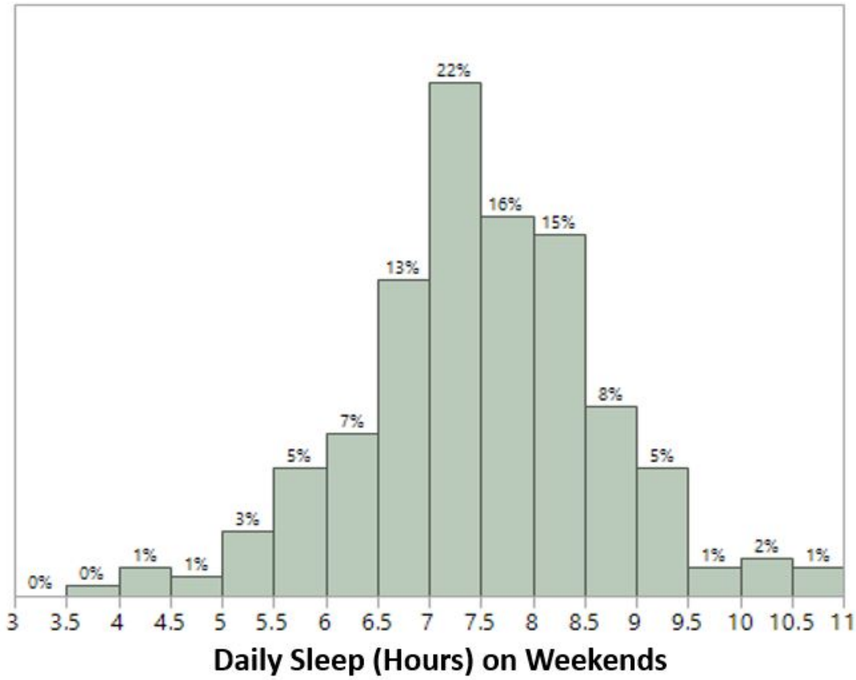

Figure 13. Distribution of average weekend daily sleep duration.

An ANOVA was conducted to determine whether year group, gender, and participation in Corps Squad athletics affected the average total duration of sleep and naps that Cadets obtained on weekends. The results indicated that both gender ($F_{1,258} = 4.00$ p = 0.047) and year group ($F_{3,258} = 4.92$ p = 0.002) were associated with Cadets' weekend daily sleep duration. The duration of daily sleep and naps on weekends, averaged based on both gender and year group, can be observed in Figure 14. The figure indicated that on average female Cadets in each year group generally slept more than their male counterparts; the 2021 (Plebe) year group female and male Cadets on average obtained more sleep and naps on the weekend than most of their peers in the other year groups. However, not all of the differences were statistically significant. A multiple comparisons test with a Tukey correction determined that the only statistically significant differences were between 2021 (Plebe) female Cadets and 2020 (Yearling) male cadets (p=0.044), and between 2021 (Plebe) male cadets and 2020 (Yearling) male cadets (p=0.050).

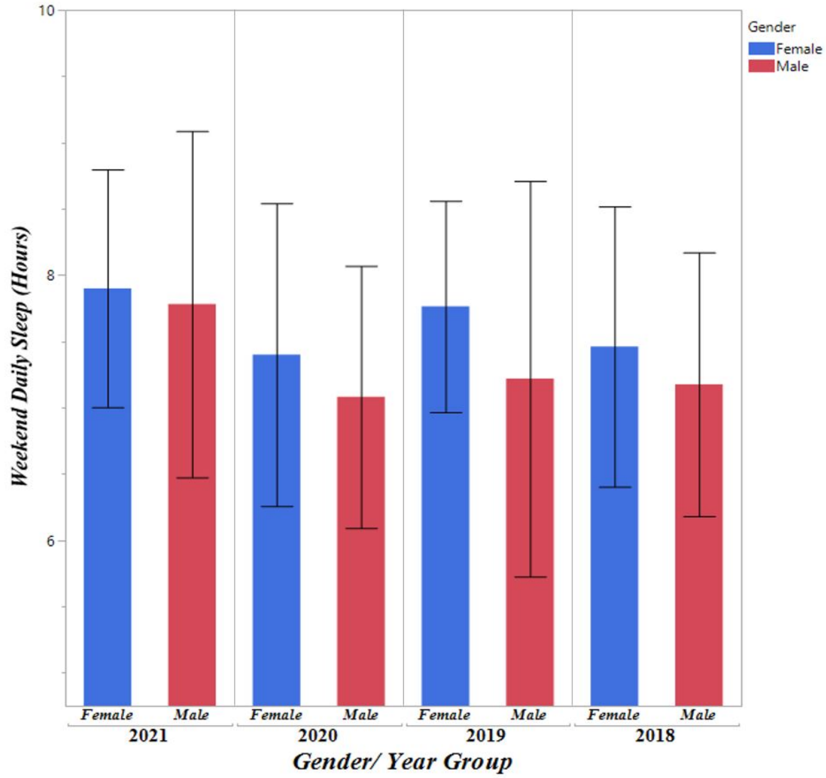

Figure 14. Average weekend daily sleep duration, stratified by gender and year group, with standard deviation annotated.

The results from the multiple comparisons test indicated that year group, primarily whether Cadets belonged to the 2021 (Plebe) class or not, could have been a strong predictor of average weekend daily sleep duration. To highlight this effect, average weekend sleep and nap durations were stratified by year group for analysis. On weekend days and nights, the average amount of daily sleep for the 2021 (Plebe) year group was 7.82 hours (7 hours and 49 minutes, SD = 1.17, median = 7.82, n = 89); the average amount of weekend daily sleep for the 2020 (Yearling) year group was 7.20 hours (7 hours and 12 minutes, SD = 1.04, median = 7.19, n = 69); the average amount of weekend daily sleep for the 2019 (Cow) year group was 7.42 hours of sleep (7 hours and 25 minutes, SD = 1.29, median = 7.34, n = 47); and the average amount of weekend daily sleep for the 2018 (Firstie) year group was 7.28 hours of sleep (7 hours and 17 minutes, SD = 1.01, median = 7.31, n = 59). These results can be seen in Figure 15. Figure 15, along with the ANOVA results, suggests that on average, the Plebe class generally obtained more weekend sleep than the other three classes.

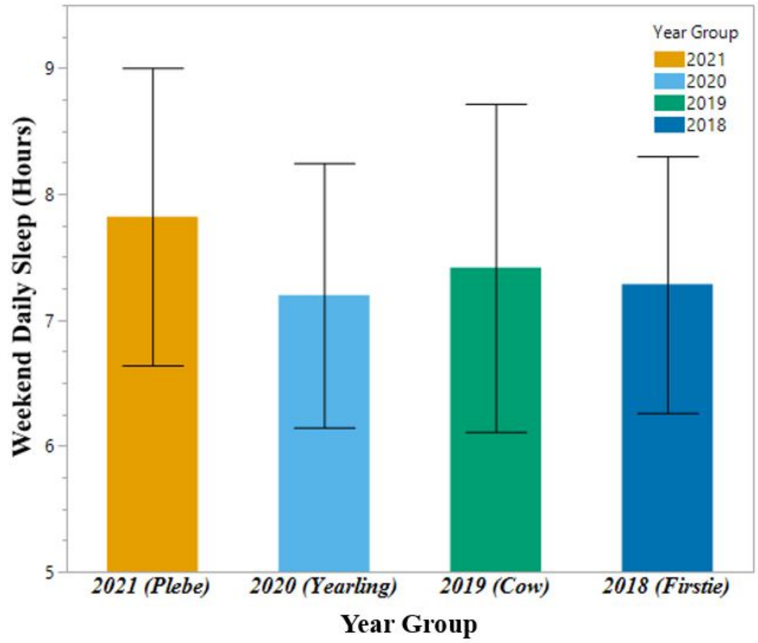

Figure 15. Average daily sleep for weekend days and nights stratified by year group with standard deviation annotated.

B. NIGHTTIME SLEEP

Nighttime sleep was defined as sleep that occurred from 8:00 PM on one evening through a participant's awakening the next morning, with the sleep being credited to the day on which the Cadet awoke. A total of 269 Cadets provided school night sleep data for analysis. Average nightly sleep was calculated for every Cadet for each day of the week. The results can be seen in Table 5 and Figure 16. As with daily sleep durations, the average nighttime sleep increased as the week progressed.

Table 5. The nighttime sleep (in hours) obtained by participants by the day of the week.

	Day of Week						
(in hours)	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Average	4.92	5.34	5.31	5.23	5.38	6.31	7.72
SD	1.04	1.01	1.01	0.96	1.00	1.32	1.37
Median	4.98	5.43	5.38	5.32	5.43	6.32	7.62
n (Participants)	257	258	262	263	267	259	250

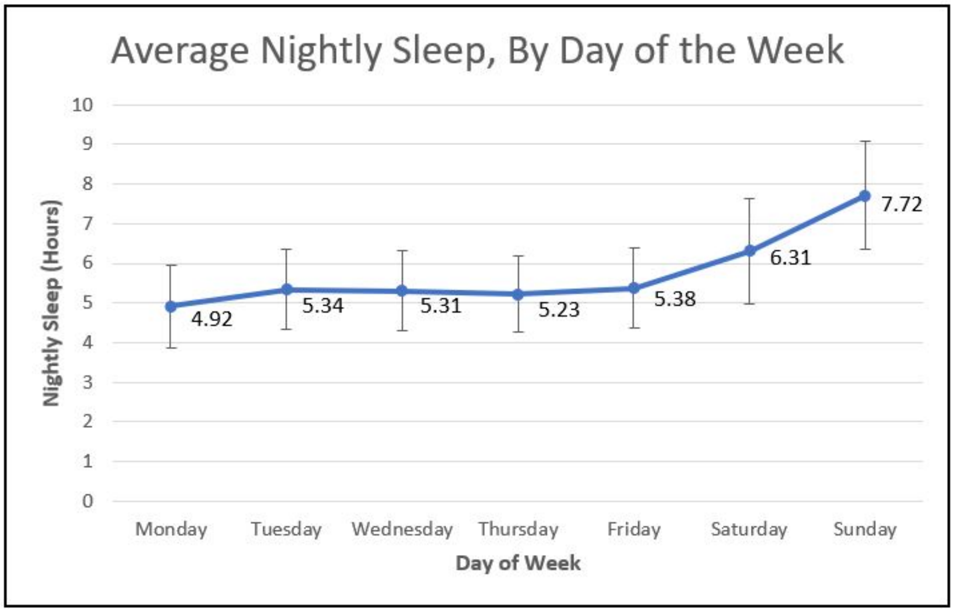

Figure 16. The average nighttime sleep obtained by the day of the week with standard deviation bars.

To determine whether the observed trend was statistically significant, a mixed-effects analysis was conducted to determine which factors from among year group, gender, day type, and participation in Corps Squad athletics, would best describe the variability in average nighttime sleep duration. The 'day of the week' predictor was again converted into the variable 'day type', which classified sleep as either occurring on school nights or weekend nights. A verification of the assumptions necessary to conduct a mixed-effects analysis indicated that homoscedasticity was not present in the average sleep duration residuals. To stabilize the residual variance, average nighttime sleep duration was transformed by taking the logarithm of the average sleep duration. The mixed-effects model was then fit, with first order interactions between the variables included in the model. The dependent variable for the analysis was the log of the average nighttime sleep duration, and the random effect was the participants. The results indicated that interactions among the factors were not necessary in the model and, as with daily sleep, year group ($F_{3,258} = 4.20$, $p = 0.006$), gender ($F_{1,258} = 7.24$, $p = 0.008$), and day type ($F_{3,258} = 624.50$, $p < 0.001$) all contributed toward explaining the variance in nighttime sleep. As in the previous results, participation in Corps Squad athletics was not significantly associated with averagesleep duration. Further analyses were conducted based on whether the daily sleep occurred on school nights or on weekend nights.

1. School Nights

Average nighttime sleep duration was calculated for each participant across all school nights. The resulting distribution of these durations can be seen in Figure 17. A one-sample Kolmogorov-Smirnov test failed to reject the null hypothesis of a normal distribution (D = 0.049, p = 0.529, n = 269), indicating that the distribution of average school night sleep could be normal. The average Cadet sleep duration on school nights was 5.24 hours (5 hours and 14 minutes, SD = 0.72, median = 5.30, n = 269).

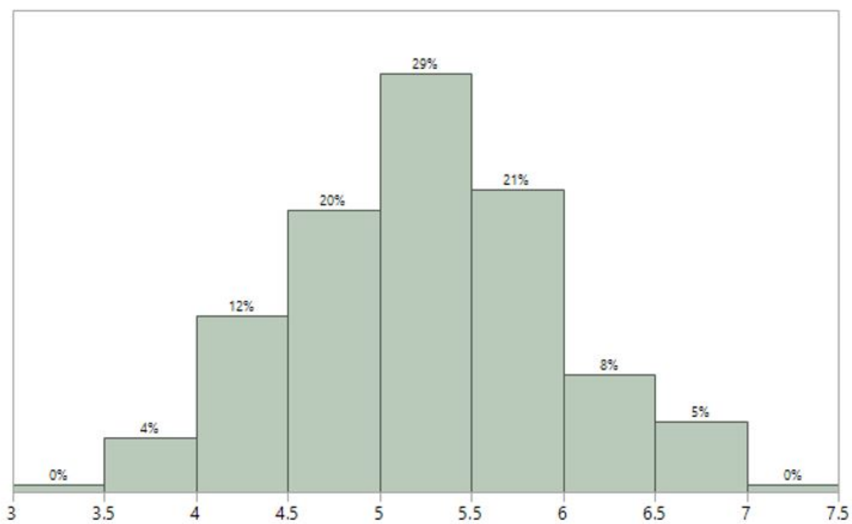

Figure 17. Distribution of average school night sleep duration.

An ANOVA was conducted to determine which factors from among year group, gender, and participation in Corps Squad athletics affected the average duration of school night sleep. As with daily sleep, the results indicated that only gender was statistically significant ($F_{1,263}$=5.08, p=0.0251). This result can be seen by comparing the average school night sleep obtained by each gender in Figure 18. On average, female Cadets slept 5.37 hours on school nights (5 hours and 22 minutes, SD = 0.68, median = 5.42, n = 95). In comparison, male Cadets slept an average of 5.16 hours (5 hours and 10 minutes, SD=0.73, median=5.18, n=174) on school nights. Female Cadets slept on average approximately 0.21 hours (13 minutes, standard error (se) = 0.08) more on school nights than their male counterparts.

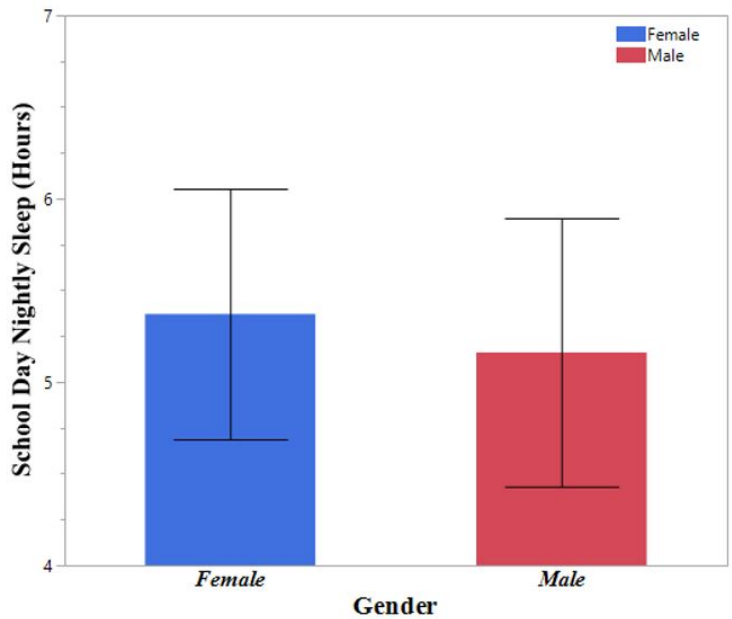

Figure 18. Average school night sleep stratified by gender with standard deviation annotated.

2. Weekends

Average nighttime sleep on weekends was calculated by averaging the duration of nighttime sleep obtained over the course of the weekend for each participant (n = 264). The resulting distribution of these durations can be observed in Figure 19. Based on the results of a one-sample Kolmogorov-Smirnov test, which failed to reject the null hypothesis of a normal distribution (D = 0.038, p = 0.841, n = 264), the weekend average nighttime sleep durations appear to be normally distributed. Cadets' average nighttime sleep on weekend nights was 6.95 hours (6 hours and 57 minutes, SD = 1.02, median = 7.02). The results from a large sample one-sided paired z-test indicated that the average duration of sleep on school nights was less than weekend nights (z = 25.404, p < 0.001, n = 264). Cadets slept on average 1.71 hours (1 hour and 43 minutes, SD = 1.09 hours, se = 0.07 hours) more on weekend nights than on school nights.

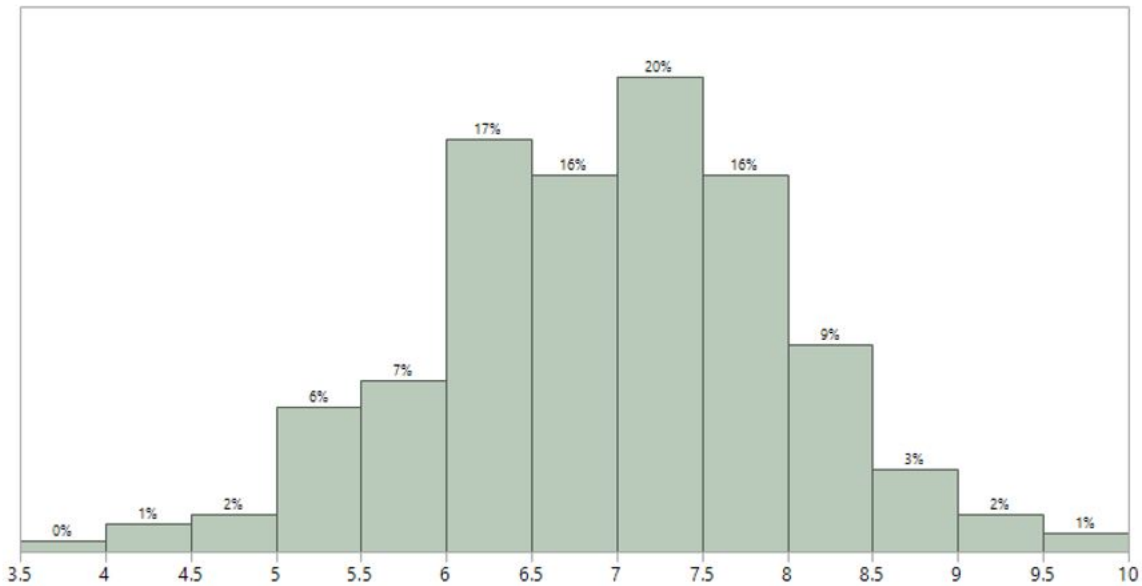

Figure 19. Distribution of average weekend nighttime sleep duration.

An ANOVA was conducted to determine whether year group, gender, and participation in Corps Squad athletics could explain the variance in the duration of weekend nighttime sleep. The results indicated that only year group ($F_{3,263}$=3.42 p=0.005) was a statistically significant effect in explaining the variability in Cadets' weekend nighttime sleep duration. The average nighttime sleep obtained by Cadets in each year group on the weekend can be observed in Figure 20. The 2021 (Plebe) year group generally slept more on average on weekend nights than the other year groups, with an average of 7.25 hours of sleep (7 hours and 15 minutes, SD=1.00, median=7.34, n=89). Cadets in the 2020 (Yearling) year group slept an average of 6.70 hours on weekend nights (6 hours and 42 minutes, SD=0.95, median=6.81, n=69). Cadets in the 2019 (Cow) year group slept an average of 6.93 hours on weekend nights (6 hours and 56 minutes, SD=1.11, median=6.88, n=47). Cadets in the 2018 (Firstie) year group slept an average of 6.82 hours on weekend nights (6 hours and 49 minutes, SD=0.94, median=6.93, n=59).

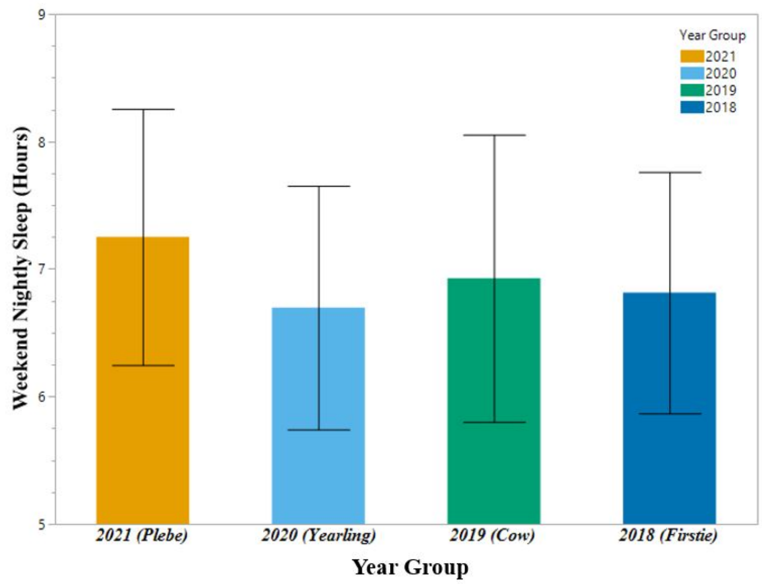

Figure 20. Average weekend nighttime sleep stratified by year group with standard deviation annotated.

A multiple comparisons test with a Tukey correction determined that the only statistically significant differences in sleep on weekend nights occurred between the 2021 (Plebe) year group and both the 2020 (Yearling) year group ($p = 0.004$) and the 2018 (Firstie) year group ($p = 0.049$). These results indicated that on average, Cadets in the Plebe class generally slept more on weekend nights than the other year groups.

3. Comparing Study Results

Miller, Shattuck, and Matsangas (2010) reported that USMA Cadets received on average 5.05 hours (5 hours 3 minutes) of nighttime sleep on school nights with a standard deviation of 1.03 hours. Cadets in the 2003-2007 study received 6.48 hours of weekend nighttime sleep (6 hours 29 minutes) with a standard deviation of 1.85 hours. In comparison, Cadets in the current study slept an average of 5.24 hours on school nights, and 6.95 hours on weekend nights. These results can be observed in Figure 21.

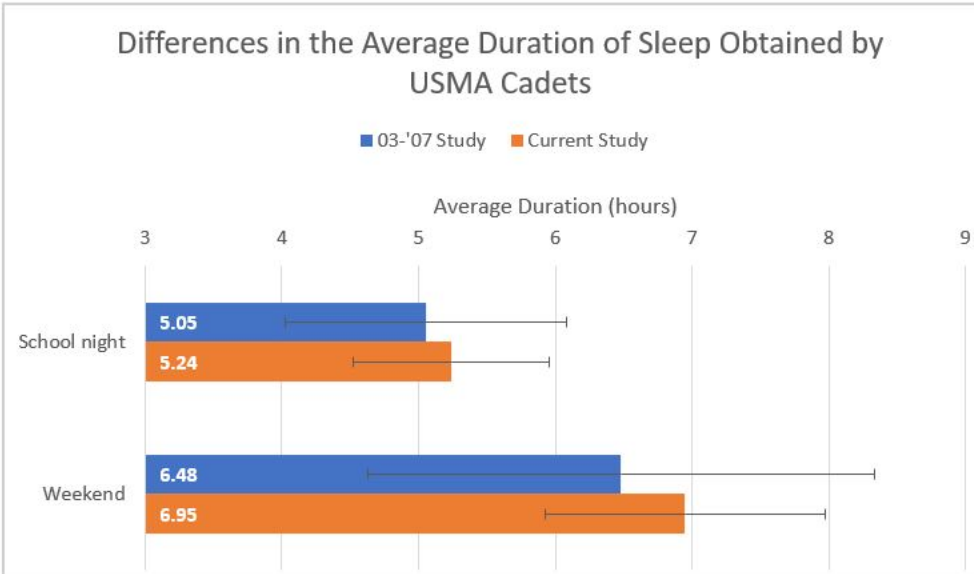

Figure 21. Comparing the school night and weekend nighttime average sleep durations reported by the 2003-2007 study and the current study.

The results from Miller, Shattuck, and Matsangas (2010) did not provide a sample size for the calculations of the previous study's sample mean and standard deviation, making a large two-sample test for differences in population means impossible to conduct. Instead, one-sample independent z-tests were conducted for both the school night and weekend nighttime sleep averages, utilizing the previous study's sample mean as a fixed value. The results of the tests indicated that on average, Cadets in the current study obtained a statistically significant amount more sleep on school nights ($z = 4.233$, $p<0.001$) and on weekend nights ($z=7.489$, $p<0.001$) than their peers in the 2003–2007 study. Current Cadets slept on average approximately 11.4 minutes more on school nights, and approximately 28.2 more on weekend nights than the Cadets in the previous study. However, a one-sample independent z-test does not account for the variability in the previous study's sleep data, which, as can be seen in Figure 21, was large for both school night sleep and weekend sleep.

To verify the accuracy of the one-sample independent z-test results, the equation for the two-sample large-sample test statistic for the difference in population means was used to determine the minimum sample size necessary that could result in statistical significance, given that the previous study's sample mean and sample variance were already known. The two-sample hypothesis test for differences in population means has large-sample test statistic z,

$$z = \frac{\bar{x}_c - \bar{x}_p}{\sqrt{\frac{s_c^2}{n_c} + \frac{s_p^2}{n_p}}} \tag{1}$$

where $\bar{x}$, s^2, and n indicate a sample's average, variance, and sample size respectively, and the "c" and "p" subscripts indicate the current ("c") and previous ("p") study. At the 0.05 level of significance, the null hypothesis of the two-sample test (there is no difference in the population means) is rejected when the absolute value of z is strictly greater than 1.96, or $|z| > 1.96$.

As the previous study's sample size (n_p) was unknown, equation (1) was solved for the smallest value of n_p which would lead to rejection of the null hypothesis at a 0.05 level of significance,

$$n_p = \frac{s_p^2}{\left(\frac{\overline{x_c} - \overline{x_p}}{z_{.025}}\right)^2 - \left(\frac{s_c^2}{n_c}\right)} \tag{2}$$

where $z_{.025}$ indicates the two-sided level of significant critical value ($z_{0.025} = 1.96$). Solving for n_p while utilizing the current and previous study's given nighttime sleep statistics for each type of day yielded the sample sizes for the previous study results. The calculation indicated that the school night sleep sample size needed to be larger than 143 to achieve a statistically significant difference in population means between the two studies. Similarly, the sample size for the previous study on weekend nights needed to be larger than 64 to achieve statistically significant differences in the weekend nighttime sleep population means. As both sample sizes appeared to be within reasonable levels based on the information provided by Miller, Shattuck and Matsangas (2010), it was concluded that current Cadets likely sleep more than their predecessors did ten years ago.

C. NAPS

For this study, naps were defined as any sleep episode that began between the hours of 6:30AM and ended by approximately 8:30PM the same day. The amount of time spent napping in a single day (including multiple naps if they existed) produced a daily total nap duration for each participant.

Average nap duration was first calculated according to the day of the week on which the nap occurred. The results for each day of the week can be found in Table 6, and the results shown in Figure 22. To test whether there were significant differences in the distributions of total average nap duration by day of the week, multiple Wilcoxon Rank-Sum tests, with test statistic W, were conducted between consecutive days. The results indicated that there were differences in the distribution of the average duration of naps on Tuesday and Wednesday ($W = 5229$, $p = 0.025$), Friday and Saturday ($W = 5695.5$, $p < 0.001$), and Saturday and Sunday ($W = 7518.5$, $p < 0.001$). These results were interpreted to mean that there was a slight increase in average nap duration on Wednesday, which then remained at similar levels until Saturday when the averageduration increased significantly, before decreasing on Sunday.

Table 6. Nap duration by day of the week.

	Day of Week						
(in hours)	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Average	1.17	1.13	1.30	1.23	1.35	2.19	1.28
SD	0.72	0.87	0.83	0.87	0.95	1.25	0.82
Median	0.93	0.87	1.15	1.03	1.08	2.07	1.18
n (Participants)	97	109	116	132	139	141	74

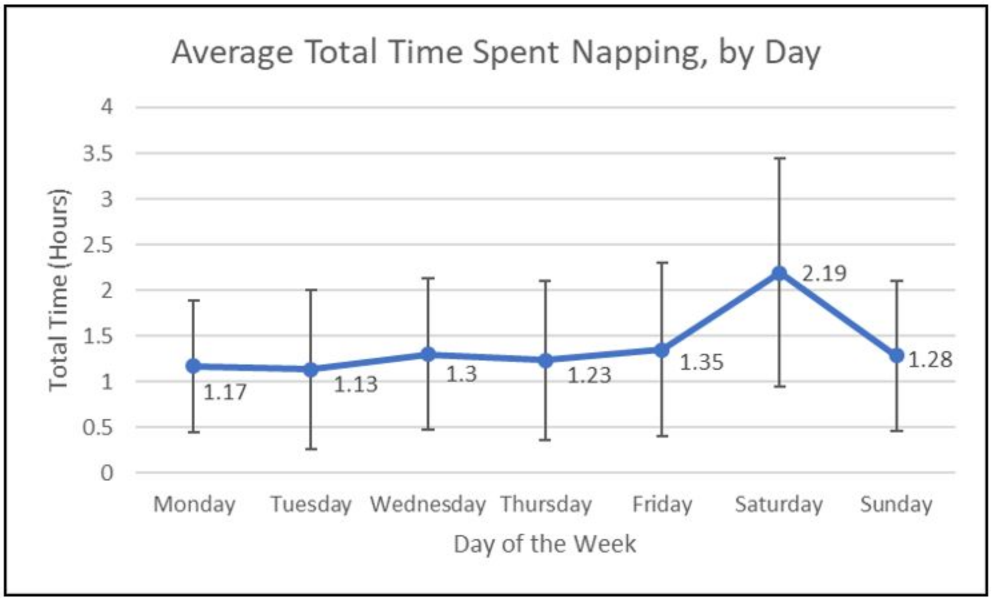

Figure 22. Total time participants spent napping by the day of the week with standard deviation annotated.

Because of the longer average nap duration on Saturday, napping durations were divided into naps that occurred on school days, and naps that occurred on weekends. The distribution of average nap durations on school days can be observed in Figure 23. The average duration of school day naps was 1.27 hours (1 hour and 16 minutes, SD=0.69, median=1.12, n=219). On weekends, the average nap duration increased to 1.93 hours (1 hour 56 minutes, SD=1.19, median=1.69, n=166), a difference of approximately 39.6 minutes. The distribution of the average duration of weekend naps can be observed in Figure 24. A one-sided Wilcoxon Rank-Sum test was conducted, to determine whether the school day and weekend distributions were different from each other. The results indicated that the distribution of the average duration of naps taken on school days was different from the distribution of average nap durations taken on the weekends ($W = 11688$, $p < 0.001$). This finding was interpreted to indicate that Cadets tend to take more or longer naps on the weekend than on school days.

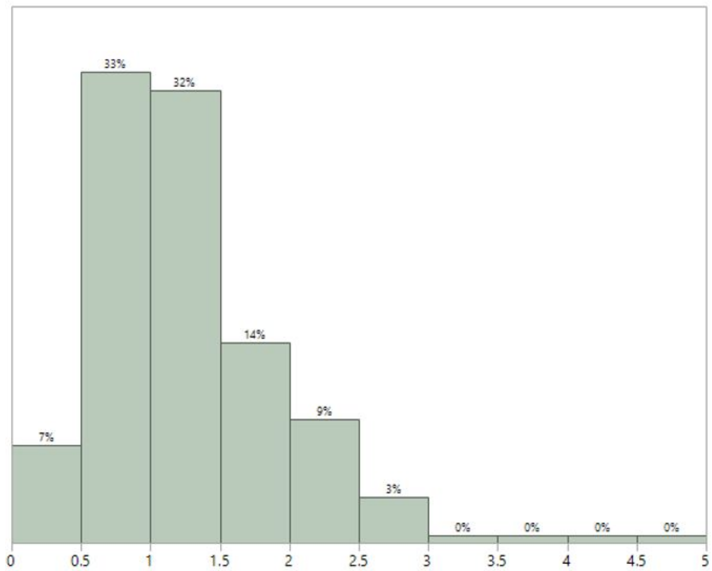

Figure 23. Distribution of the average duration of naps taken on school days.

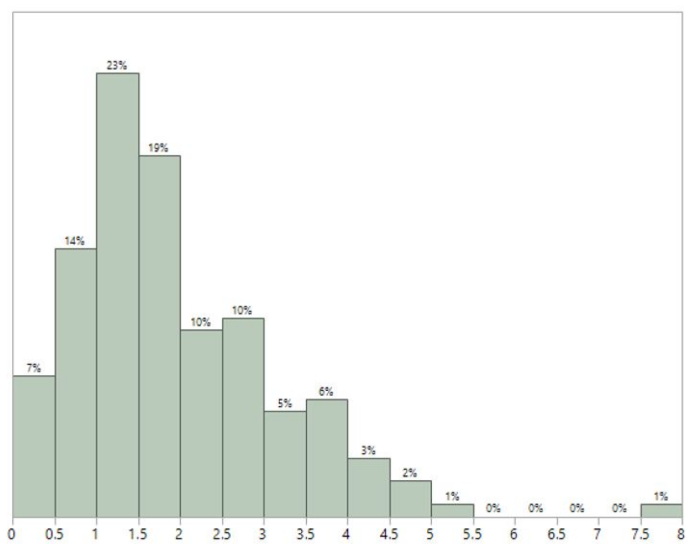

Figure 24. Distribution of the average duration of naps taken on weekends.

In addition to calculating the average nap duration, a count of the number of participants who napped from 0630 (6:30AM) through 2000 (8:00PM), in 15-minute intervals for each day of the week, was taken. The resulting counts were then graphed to determine what days of the school week and at what times Cadets were most likely to take a nap. The results can be observed in Figure 25 and indicate that a portion of Cadets nap in the morning from approximately 7:00AM through 9:00AM, with the highest number of morning naps generally occurring on Friday. However, most Cadets napped during the afternoon hours from 1300 (1:00PM) to 1545 (3:45PM), although those hours were extended even further into the evening up to approximately 1800 (6:00PM) on Wednesday and Friday for many Cadets. The highest number of nappers occurred on Thursday afternoon, with Friday and Wednesday afternoons falling closely behind.

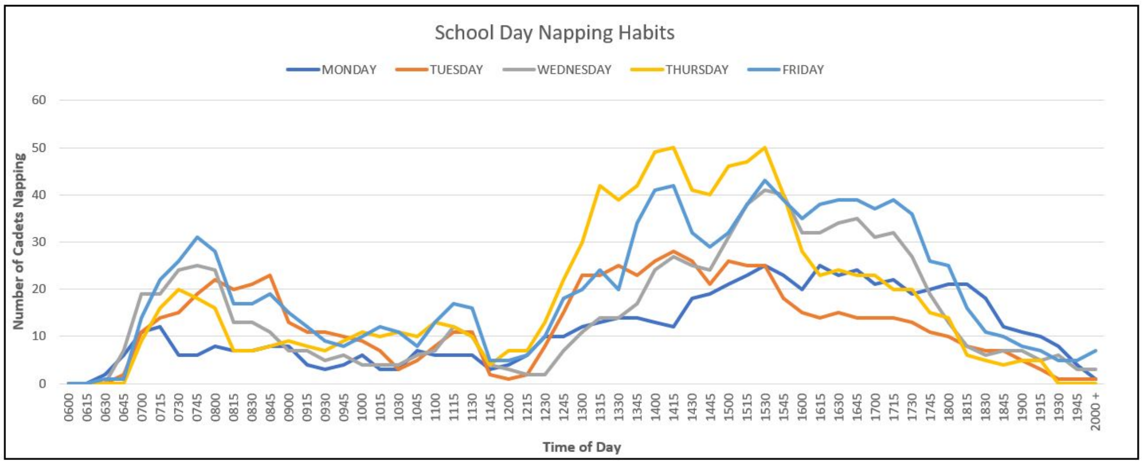

Figure 25. Number of Cadets napping during school days.

Multiple Wilcoxon Rank-Sum tests were conducted to determine whether there were differences in the distributions of nap duration based on year group, gender, or participation in Corps Squad athletics. None of the tests returned statistically significant results, indicating that day of the week or day type (school day or weekend) appear to be the only significant predictors of nap duration.

D. ACTIVITY LOG RESULTS

Each study participant was asked to fill in an electronic activity log as part of their participation in the sleep study, allowing researchers to track the types of activities participants conducted throughout each day. Ten activities were pre-defined: sleep/rest, hygiene, meal, class, study, military duties, leisureDigital, leisureNonDigital, athletic, and other. A short description of each of these types of activity can be found in Table 7.

A set of 31 participant activity logs were used for the activity log analysis. Although more activity logs were available, only 31 were complete and thereby provided accurate representation of Cadet's daily activities. The daily durations of each of the 10 activities were calculated for each participant, for every day that the participant completed their activity log entries. These results were then analyzed to create an average duration for each activity, according to whether the activities occurred on a school day (Monday through Friday) or on a weekend. The resulting participant durations were then consolidated to provide an average amount of time that USMA Cadets spent on each activity during school days and on weekends. The results are summarized in Table 7. Although it is not noted in the table, the sum of each of the school day and weekend average times for each activity was 24 hours.

Table 7. Average reported duration of time that Cadets spend on ten specified activities, on school days and on weekends.

ACTIVITY	DESCRIPTION	SCHOOL DAY /WEEKEND	AVERAGE TIME (HOURS)	STANDARD DEVIATION
Sleep/Rest	Time spent in bed attempting to sleep	SCHOOL DAY	6.8	0.9
		WEEKEND	**8.6**	**1.2**
Hygiene	Showering, etc.	SCHOOL DAY	0.8	0.4
		WEEKEND	**0.6**	**0.4**
Meal	Eating or at a meal(s)	SCHOOL DAY	1.4	0.4
		WEEKEND	**1.0**	**0.5**
Class	Receiving instruction	SCHOOL DAY	3.9	1.1
		WEEKEND	**0**	**0**
Study	Studying on one's own	SCHOOL DAY	4.6	1.9
		WEEKEND	**3.9**	**2.3**
Military Duties	Military required training, events, or requirements	SCHOOL DAY	1.8	1.2
		WEEKEND	**2.4**	**1.5**
LeisureDigital	Free time spent on TV, electronic games, cellphone or computer (not for school)	SCHOOL DAY	1.3	1.1
		WEEKEND	**2.8**	**2.1**
LeisureNonDigital	Free time spent on items that do not involve a digital screen	SCHOOL DAY	1.2	1.2
		WEEKEND	**2.4**	**2.1**
Athletic	Exercise: USMA Athlete, Club participant, or personal reasons	SCHOOL DAY	1.5	1.0
		WEEKEND	**0.7**	**1.3**
Other	Activities not mentioned above	SCHOOL DAY	0.7	0.6
		WEEKEND	**1.6**	**1.7**

Cadets reported spending an average of almost 2 hours more time sleeping and napping on the weekends than they did on school days. They also reported spending more time studying on school days than on weekends, and they tended to spend more time on Military Duties on the weekends than they did on school days. As expected, Cadets tended to spend more time on leisure-type activities (both leisureDigital and leisureNonDigital, as well as Other) on the weekends than on school days.

An interesting result from the activity log analysis was the difference between the sleep and nap duration that the Cadets reported in their activity logs and the average daily sleep duration calculated from their actiwatch data. Cadets who completed their activity logs reported sleeping on average 6.78 hours (SD = 0.94 hours) on school days and 8.6 hours (SD = 1.20 hours) on weekends. In comparison, those same Cadets' actiwatch results indicated they obtained an average of 5.74 hours of daily sleep on school days (SD = 0.72, n = 29) and 7.89 hours of daily sleep on weekends (SD = 1.16, n =28). This finding resulted in an average difference of 1.0 hours of sleep on school days (median = 0.95, SD = 0.59) and 0.68 hours of sleep on weekends (median = 0.74, SD = 0.73). Wilcoxon Rank-Sum Tests indicated that the distributions for activity-log calculated school day daily sleep and actiwatch-determined school day daily sleep were statistically different ($W = 717$, $p < 0.001$), as were the difference in distributions of activity-log calculated and actiwatch-determined weekend daily sleep ($W = 621.5$, $p = 0.005$). The large difference between activity-log reported sleep and actiwatch-recorded sleep indicates that Cadets may believe that they are sleeping more than they actually are. It also confirms the results of previous studies, which found that self-reported activity logs were generally not an accurate representation of sleep, compared to passively recorded actigraphic results.

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V. DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

A. DISCUSSION

Overall, Cadet sleep patterns in the fall semester of 2017 were influenced by the same factors as those found in the Miller, Shattuck and Matsangas (2010) study. Significant predictors included day type (school day or weekend), gender, and year group. Participation in Corps Squad athletics was not statistically significant in any of the analyses. We had hypothesized that Corps Squad athletes sleep more than non-Corps Squad athletes. Because Corps Squad athletes' physical health is a major focus of the Academy, we theorized that those individuals may have received more guidance on the positive effect of sleep on physical performance than non-Corps Squad Cadets. Notably, Mah, Mah, Kezirian and Dement (2011) observed significant improvements in physical performance in collegiate athletes who obtained extra sleep; it follows that USMA Corps Squad athletes' performance could benefit from gaining additional sleep.

A comparison of average nighttime sleep on school days and weekends indicated that current Cadets tended to sleep slightly more at night on both school days (5.24 hours) and weekends (6.95 hours) than their predecessors from ten years ago (school days = 5.05 hours, weekends = 6.48 hours). This finding refutes the original hypothesis for this thesis, which posited that current Cadets were likely obtaining the same or less sleep than the Cadets in the previous study. Although current Cadets' nighttime sleep was on average 11.4 minutes more on school days than their predecessors (and 28.2 more minutes than their predecessors on weekends), the substantial sleep debt that Cadets accrue while attending USMA means that even a ten-minute gain in nighttime sleep may impact Cadets' daily performance. As shown in Miller's (2005) study results, every bit of additional sleep could potentially impact Cadet cognitive effectiveness, and thus, their ability to learn.

Miller, Shattuck, and Matsangas (2010) noted that Cadet sleep duration generally trended along two distinct patterns. On average, Cadets slept more (both at night and daily) as they progressed through their four years at the Academy; and Cadets tended to obtain more nighttime and daily sleep in the fall semester than in the spring semester. The current study only analyzed sleep from the fall semester; consequently, it is possible that the trend of more sleep may not extend to the spring semester. To determine conclusively whether current Cadets are actually sleeping more than they were ten years ago, the analysis must include results from data collected in the spring of 2018.

The results from the current study indicate that Plebe Cadets (year group 2021) tended to sleep more on weekends (both daily and nighttime) than the other three-year groups, although not all of the differences in average weekend sleep duration were statistically significant. As for the average daily and nighttime sleep duration measured on school days, year group was not a significant predictor of school day average daily and nighttime sleep durations, indicating that any differences in sleep duration when accounting for Cadet year group were likely minimal. This finding differed from the results published in the Miller, Shattuck and Matsangas study, which concluded that Cadets tended to obtain less daily sleep during their Plebe year than during the other three years.

Gender continued to be a significant predictor of average Cadet sleep duration, similar to the previous USMA study; however, it was less significant than in the previous study. Miller et al. found significant differences in gender across academic year, semester, and day of the week. In the current study, the differences in average sleep between the genders only achieved statistical significance when examining the sleep duration on school days for both daily sleep (0.23 hours difference, with female Cadets obtaining more sleep) and nighttime sleep (0.21 hours difference, with female Cadets again obtaining more sleep). While gender was significantly different for average weekend daily sleep durations, when the duration was stratified by both year group and gender, the multiple comparisons test revealed only a single significant difference in average sleep duration between the genders. This result indicates a possible trend, whereby female Cadets generally sleep more on average than male Cadets on school days, but male tended Cadets sleep as long or longer than female Cadets on weekends.

On school days, Cadets napped an average of 1.27 hours, while on weekends Cadets napped an average of 1.93 hours, indicating that Cadets tended to nap longer on the weekends than on school days. Cadets in the current study were also most likely to nap on Thursday, followed by Friday and Wednesday. This finding is different from Godfrey

(2006) who concluded that Cadets from the Class of 2007 napped the most on Wednesdays. The reason for this difference is unclear; it may be that the USMA schedule and/or policies have changed with respect to naps. Considering that USMA Cadets accrue a hefty sleep debt each week, it is understandable that they nap to supplement the meager amounts of sleep that they get.

B. CONCLUSION

This study reported the results from the first half of a two-part study on USMA Cadet sleep duration and time-usage, analyzed from data collected in the fall of 2017. It also compared the results to those obtained from a longitudinal study of USMA Cadet sleep conducted from 2003-2007 by Miller, Shattuck, and Matsangas (2010) at USMA.

The results from this analysis indicate that Cadet average sleep (both nighttime sleep and daily sleep) is influenced by day type (school day or weekend), gender, and year group, similar to the results reported by Miller, Shattuck, and Matsangas (2010). On school days, Cadets slept an average of 5.61 hours daily (SD = 0.72 hours), although female Cadets (average = 5.76 hours) slept 9 minutes longer on average than male Cadets (average = 5.53 hours). This result is similar to the results reported by Miller, Shattuck, and Matsangas (2010), who found that gender influenced sleep duration. On weekends, Cadets slept an average of 7.47 hours, approximately 1.86 hours more than on school days. Weekend sleep duration was determined by both Cadet gender and year group, although the results from an ANOVA and a plot of Cadets' average weekend daily sleep by year group indicated a trend of year group 2021 (Plebe) Cadets tend to sleep at least as much, if not more, than Cadets in the other year groups.

Current Cadets slept an average of 5.24 hours (SD = 0.72) on school nights, although female Cadets (average nighttime sleep = 5.37 hours) again on average slept significantly longer (12.6 minutes or 0.21 hours) than male Cadets (average nighttime sleep = 5.16). As occurred in the daily sleep analysis, this significance in gender confirmed the findings of Miller, Shattuck, and Matsangas (2010). Average nighttime sleep on weekends differed by year group, with year group 2021 (Plebe Cadets) sleeping on average at least as long or longer than the other year groups, as was indicated in the daily weekend sleep duration analysis. The average amount of nighttime weekend sleep that Cadets obtained was 6.95 hours (SD = 1.02).

A comparison of average school day and nighttime sleep durations between the Miller, Shattuck, and Matsangas (2010) study and the current study indicated that on average, current Cadets sleep slightly more than Cadets a decade ago. On school nights, the difference between the current and previous average durations was 0.19 hours (11.4 minutes) while on weekend nights, the difference between the current results and previous average durations was 0.47 hours (28.2 minutes).

Cadet napping habits were also examined as part of the study. The analysis indicated that Cadets who napped obtained an average of 1.27 hours (SD = 0.69) of additional sleep on school days, and 1.93 hours (SD = 1.19) of additional sleep from naps on weekends. The largest number of Cadets napped on Thursdays, followed by Fridays.

While the slight increase in the average amount of nighttime sleep that USMA Cadets obtain is positive, the fact remains that the 5.24 hours that Cadets sleep on average during school nights is still well below the nationally recommended average of 7 to 9 hours of sleep for this age group. Even the school day daily sleep and nap average duration of 5.61 hours falls woefully short of the minimum recommendation. USMA Cadets continue to operate under significant sleep deprivation conditions for their age group. These results indicate that while USMA leadership has taken a step in the right direction with their policies and procedures in the last ten years, there is still much more to do to improve Cadet sleep patterns, and thus unlock Cadets' full academic and physical performance potential.

C. RECOMMENDATIONS FOR FUTURE RESEARCH

1. Prediction Variables

The current research focused on sleep data collected from Cadets in the fall semester of 2017. It found that the day of the week, day type, gender and year group were all associated with Cadet sleep duration. However, Miller, Shattuck, and Matsangas (2010) found that in addition to the predictors mentioned, the semester that the sleep occurred in (fall or spring) was also significantly associated with average Cadet sleep duration. More importantly, Miller, Shattuck and Matsangas reported that on average, Cadets slept less in the spring semester than in the fall semester. While the current analysis provides encouraging information on the state of Cadet sleep, the sleep durations which occur in both semesters of the academic year are necessary to conclusively determine whether current Cadets are sleeping more than their predecessors.

Sleep duration is an important indicator of human well-being, but the fact remains that sleep duration itself does not tell the whole story. Chronic sleep deprivation can have serious detrimental effects on human health and performance. In the case of USMA Cadets, academic and military grades and health status may also be related to their sleep duration. An analysis including these factors would provide the USMA leadership and researchers a more accurate indication of the deleterious effects of sleep deprivation and speak to the benefit of promoting healthier sleep patterns.

2. Sample Sizes

The results from this study indicated that on average, Corps Squad athletes did not get significantly more sleep than non-athletes in the fall semester. However, only a small percentage of Corps Squad athletes were recruited for the study (48 total or approximately 18% of Cadet participants). In future studies, Corps Squad athletes should be over-sampled, as female Cadets were for the current study, to determine whether differences in sleep duration exist. Alternatively, a study which focused solely on the sleep of Corps Squad athletes could determine whether an increase in sleep duration would translate to an increase in athletic performance, as was reported by Mah, Mah, Kezirian and Dement (2011).

This analysis concluded that the 2021 (Plebe) year group's average sleep duration on both school nights and weekends was no longer the lowest of all the year groups, as was reported by Miller, Shattuck and Matsangas (2010). While factors not considered in this analysis could explain the increase in Plebe (year group 2021) average weekend sleep in the intervening years, it is possible that the Plebe average sleep duration highlighted in this analysis reached statistical significance due to the larger sample of Plebe Cadets who participated in the current study, as compared to the sample sizes of the other year groups. Future studies should attempt to balance the sample sizes of the various groups of Cadets as much as possible to minimize the influence that larger sample sizes from one subset of the sample population could have on the statistical significance of test results.

3. Electronic Activity Logs

Requiring participants to fill out a daily activity log is a standard procedure in field-based sleep studies. In the current study however, USMA leadership had specific questions about the Cadets' time utilization and requested that Cadets be asked to track their activities for every hour of every day. An app was developed that allowed Cadets to easily track their daily activities using smart phones, laptops or tablets. Activity logging compliance in the study was less than desired, however; Cadet responses were erratic. Ultimately, only 31 activity logs (out of 264 possible logs) of various lengths of time were considered complete enough to be included in the time utilization analysis. Using the electronic activity log was helpful in minimizing researcher transcription errors, which often occurs in the paper and pencil version of activity logs. Digitization also allowed researchers to judge the accuracy of the log entries by calculating the length of time between the Cadet's data entry and the day for which the Cadet was logging the activities. These factors made the use of an electronic activity log attractive for research. However, the requirement to account for 24-hours of activities for each day of the study was likely overly burdensome to Cadets already going through a rigorous and stressful college experience. Future studies should examine the requirement to keep such detailed activity logs, and whether or not utilizing electronic activity logs affects log completion.

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